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VOLUME VII

A MANUAL OF UNDERGROUND SURVEYING

TRUMBULL

FIG. 1.—ILLUMINATING THE CROSS WIRES.

A MANUAL OF
UNDERGROUND SURVEYING

BY

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WITH ILLUSTRATIONS

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TO

HIS FATHER

THIS BOOK IS LOVINGLY DEDICATED

BY THE AUTHOR

PREFACE

The author has tried in this work to meet the often expressed wish of students, teachers, and practicing surveyors for a book giving the best of American practice. As a teacher the author found it necessary to work up lectures upon mining surveying. These have formed the basis of this work.

The author makes no pretense of presenting original material. This book is frankly a compilation from various sources. Articles printed in the various magazines and publications of the technical societies have been drawn upon freely, as have also the catalogues and literature of the different firms of instrument makers.

The descriptions of surveys, or methods of work, given by the engineers who made them, are reprinted in full, as they were printed in the publications to which credit is given. They represent best surveying practice, and fulfill the purpose as an object lesson to the student better in their original form than would a review or synopsis.

While much of the material given has appeared in print before, much of it is new; written for this particular purpose by engineers who are busy every day with the actual underground work. The engineers of many of the largest mines of this country have kindly furnished the author with detailed descriptions of the methods in use at their properties. To these engineers we extend our sincere thanks. Without their assistance this book could not have been written.

Realizing fully that there are usually several equally good ways of doing a thing, the author has tried to give a description of the several most-used and best ways of doing each thing, without allowing his personal preference for any particular method to prejudice it.

The author wishes to acknowledge his indebtedness to the various instrument makers who have furnished cuts to illustrate the instruments used in underground work. While unable to thank by mention each engineer who has aided, encouraged, and

helped to write this book, the author wishes especially to thank E. S. Grierson, chief engineer of the Calumet & Hecla; R. H. Britt, manager of the Poorman; Mr. Howard Spangler, chief engineer of the Portland; Mr. August Christian, chief engineer of the Anaconda Copper Mining Co.; C. W. Goodale, chief engineer of the Boston and Montana; Mr. Howard Eavenson, chief engineer United States Coal and Coke Co.; Mr. Lucien Eaton, superintendent of the Iron Belt Mine; Prof. Mark Ehle, Jr., of the South Dakota School of Mines; Mr. James Underhill of Denver, Colo., and Prof. L. E. Young, director of the Missouri School of Mines. Our thanks are extended also to the many authors and publishers who have given their permission to reprint articles which have been printed before.

NOTE. — This book is expected to be used only with students who have an understanding of Plane Surveying. No attempt is made in this volume to teach ordinary surveying methods or theory. While the work has been cross referenced to a considerable extent the reader is advised to make constant use of the index. Where a special method or piece of apparatus is explained by another author in a quotation or special article the subject matter of such explanation has not been repeated in the general discussion of such method or apparatus. The index has been made especially full and complete so that every item in the book upon any subject may be readily found. For this reason teachers will find it of advantage to teach by subjects, rather than by chapter or given number of pages. The bibliography of each topic will be found at the close of each chapter, and should be of use to both teacher and student.

LOYAL W. TRUMBULL.

DOWNIEVILLE, CALIF., *March*, 1908.

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A MANUAL OF UNDERGROUND SURVEYING

I

INSTRUMENTS

Surveying is the art of making measurements which determine the relative position of two or more points. Mine surveying is the art of surveying underground openings, i. e., finding the relative positions of points under the surface, or the position of points underground relative to points upon the surface. The angles and distances measured are usually drawn to scale upon various planes and mine maps thus produced.

In mine surveying there are but few operations different from those of plane surveying. The application of the same principles to the different conditions, along with a greater degree of accuracy, insures success underground.

T. A. O'Donahue, in 'Colliery Surveying,' says: 'Surveying is the art of taking such measurements and observations of an object as will enable a true proportionate representation to be drawn on a plane surface. The principles upon which it depends are all embodied in the science of geometry; so that surveying may be said to be a practical application of geometry.'

Johnson, in his 'Theory and Practice of Surveying,' p. 431, says: 'Surveying is an art, not an exact science.' This should be kept constantly in mind, and in every case that method which promises the minimum deviation from the scientifically correct result should be employed.

The Transit Theodolite

The instrument now almost universally used for the measurement of angles is the transit theodolite, or more commonly, 'transit.' While other instruments are still used upon occasion the transit is the engineer's standby. In times past various more or less accurate, but now antiquated, instruments have served for underground work. As these are of historical interest only, a description of them will not be given.

Other instruments which replace the transit for certain work, or act as an auxiliary to it, will be described later.

Each engineer has his own preference when it comes to choosing

FIG. 2. — TRANSIT.

a transit, both as to make and as to the attachments used. There are a number of reliable makers, each putting good transits on the market. Whatever the make there are certain constructions

which are generally admitted to be best for certain kinds of work.

For underground work, especially in the metal mines in rough country, a light transit, commonly known as a 'Mountain Transit,' is favorite. It should be mounted upon an extension tripod. Not only is this a necessity in work underground, but it is a wonderful convenience when traveling.

The horizontal circle is about 6 inches in diameter and is graduated to read from 0° to 360° in both directions. A full vertical circle, brazed to the horizontal axis and protected by an aluminum guard, is now commonly used. Both circles read to minutes.

The telescope should magnify about twenty times, not more than twenty-four times, erect image, and should focus upon points at 4 feet distant. A prismatic eyepiece is a convenience but not a necessity. An auxiliary telescope is, or is not, a necessity according to the kind of work to be done. The transit should, however, always have the connecting nipples upon it so that the auxiliary may be obtained and used at any later time, if necessary.

The telescope bubble should be long, for in most cases the elevations will be obtained by use of the transit, either by carrying them, as with the ordinary level, or by means of the vertical angles.

Several of the makes of transits most used by mining engineers are illustrated. Some show an auxiliary telescope, others do not. Each maker usually furnishes either top or side telescope and any other attachments desired. Each publishes a small catalogue and manual explaining his instruments. The user of a transit should certainly have a copy of the catalogue published by the makers of the instrument he uses, and the student can well afford to spend many hours studying them.

To show the variance in opinion regarding the best transit for use underground, the following quotation from the *Engineering and Mining Journal* of August 23, 1907, is given:

'It must be of high enough grade to allow of good triangulation work, and not too sensitive for rough usage; light enough to carry around the surface and on distant surveys in a mountainous country, and the horizontal circle graduated to 20 seconds of arc. For average surface work, moderately high magnifying powers are demanded; but the underground work will be at close

range and in poor light where small magnification is better. Taking all things into consideration, probably a 4- to 4½-inch horizontal circle reading to 20 seconds, full vertical circle, U-shaped standards light mountain transit will outline the best instrument for the work. It should be procured from the best American manufacturers, and will be expensive. Something can be saved by omitting some of the usual extras. The U-standards and small circle will do away with a compass in the usual place. This omission will be disapproved by some, largely from habit, I believe. As a matter of fact, the compass, as an attachment to the

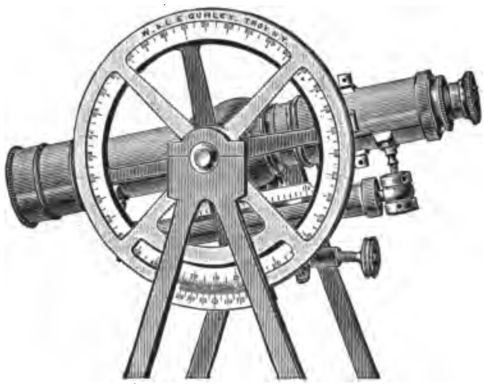


FIG. 3. — GUARD FOR VERTICAL CIRCLE.

transit, does not earn its salt, and is a distinct disadvantage in the correct construction of the instrument itself.

'The U-standard offers so many decidedly valuable constructive advantages that its use is to be always recommended. It will permit of lighter and at the same time more substantial construction. It presents a better appearance and is less apt to get out of order. Many would hesitate to use a 4-inch horizontal circle in triangulation work, but the amount of such work is small, permitting of extra care in repeating angles and of doing it on clear, still days.'

As the transit is strictly a product of American engineering, and as it is now used to the exclusion of all other instruments, except in rare or unimportant work, it has seemed proper to give a short history of its invention and introduction. To the student who wishes to study in more detail the history of engineering in-

FIG. 4.—MINING TRANSIT WITH TOP TELESCOPE.

struments, we recommend the scholarly and detailed articles in the *Transactions of the American Institute of Mining Engineers.*

The following short history of the transit is taken from the catalogue of Young & Sons, for whose permission to use it acknowledgment is gladly given:

'*Invention and Introduction of Engineer's Transit.* — The first transit instrument was made during the year 1831. It was a long stride in the improvement of engineering instruments; and that it should to-day retain its almost identical first form, proves the value of its introduction and the good judgment of the inventor.

'The English theodolite, capable of performing the same work, found, if we are to credit the traditions of earlier members of the engineering profession, but little favor with the American engineers. Its workings were slow and inconvenient. Few cared to trust the prolongation of a straight line by reversing the theodolite on its center, and trusting to the vernier readings; and as few fancied the trouble of reversing telescope on its Y bearings, "end for end." Forgetfulness in fastening of clips resulted in fall of the telescope, while if clips were too tight there was the danger of shifting the instrument in fastening, or if too loose, the telescope rattled. Such were some of the discomforts attending use of the theodolite, an instrument well fitted for many purposes, and whose peculiar merits still cause many of our English brethren to cling to its use.

'From the theodolite the change was to the Magnetic Compass. This, in its simplest form, or in its modified form, made to read full circle angles independent of needle, was high in favor with many, especially those surveyors who, from their local knowledge (and some with naught besides), were selected to "run" the preliminary lines of railroads. By dint of labor, these surveyors mastered the intricacies of the vernier, but could never be brought to doubt the superior virtues of compass sights in seeing past a tree or other obstruction. With the transit the tree had to come down; they would not undertake to say the staff on the other side of a tree was in line of the cross web, but were sure they could make it "just right" with the line of sights. Nevertheless, though frequently doing close work, the needle would play pranks that produced much trouble; and though to be commended for speed on the preliminary, was rather too uncertain for location.

'In the year 1831, the first transit was made by William J.

Young. It was graduated to read by vernier to 3 minutes, it being in early days a favorite idea of inventors that graduations of 3 minutes could be easily read to one minute, and was less perplexing to use. The instrument had an out-keeper for tallying the outs of the chain, and a universal or round level. The needle

FIG. 5. — MINING TRANSIT WITH SIDE TELESCOPE.

was about 5 inches, the telescope 9 inches, of low power. The standards were of almost identical pattern now used by some makers. The center between plates was of flat style, vernier on inside of the needle ring, and the plates moved upon each other by rack and pinion. The plates and telescope detached from the

tripod fastened, we believe, when attached, by a snap dragon, as in later instruments.

'For whom the first transit was made, the records, as far as we can find them, do not positively show; as well as it can be gathered from them, and from other data, the first one was used on the State works of Pennsylvania, but whether on the Mountain Division or on the Inclined Plane of Columbia Railroad, is uncertain.

'The distinguished engineers of the Baltimore & Ohio Railroad also claim the use of the first transit; and as illustrative of their belief, we append the following extract from *Railroad Journal* of December, 1855:

'"The transit is now in common use in this country, and is a comparatively cheap instrument. Such, however, is not the case in Europe. In England, the old mode is still in vogue, to a great extent, of laying out curves with the use of ordinates; we are not sure, indeed, that any other course is not an exception.

'"Some years since, Mr. Charles P. Manning, an accomplished American engineer—now the efficient chief of the Alexandria, Loudoun & Hampshire Railroad—went to Ireland, and on the Limerick & Waterford Railway, initiated the method, so common in this country, of laying out curves with the transit.

'"The first instrument of this name was made by Mr. William J. Young, the accomplished mathematical instrument maker, of Philadelphia, for the Baltimore & Ohio Railroad Company, the engineers of which made the first suggestions modifying the old theodolite. We have in times past used this instrument, which is much like those made at the present time by the same manufacturer, and is, if we are not mistaken, still in the field.

'"Since then, transits have been little improved, but have been changed in the wrong direction. They are generally much heavier than formerly, containing as much brass and mahogany as one man can well stand under. This great weight is not only useless, but dangerous. Heavy instruments are much more liable than light ones to get out of adjustment on transportation, even in the ordinary field service. They are not a whit steadier in the wind; being generally made with clumsy tripods and large plates, they expose a greater area to the breeze. If the feet of the tripod be firmly planted, the instrument is rarely disturbed by the wind. Besides this, a heavy instrument is much more liable to danger from accident in a rough country."

'And the following, from same journal of January 5, 1856:

'"*The First Transit Compass.* — In our issue of the 15th of December, 1855, in noticing the field book of C. E. Cross, C.E., we took occasion to state some facts concerning the first transit compass, an instrument made by Young, of Philadelphia. We have since then received an interesting letter from Mr. Charles P. Manning, whom we mentioned as having initiated in Ireland the American method of laying out curves. Mr. Manning disclaims the honor in favor of Richard B. Osborne, Esq., an engineer who received his professional education in the service of the Reading

FIG. 6. — DOUBLE OPPOSITE VERNIERS ON VERTICAL CIRCLE.

Railroad Company, under Messrs. Moncure and Wirt Robinson (where he finally occupied the responsible position of chief of the engineer department, during the early struggles of that corporation, in its competition with its rival, the Schuylkill Navigation Company), and from which road he went to Ireland, and took charge of the location and construction of the Waterford & Limerick Railway in 1846.

'"Mr. Manning says further: 'I obtained from Mr. Young, and sent to Ireland, probably, the first transit compass ever known in that country or in England; and soon afterwards joined Mr. Osborne as his principal assistant, for the purpose of aiding him in the effectual introduction, at least upon that road, of the American system of location and construction.'

'"We were familiar with these facts when we made the statement which Mr. Manning desires corrected. But our object was not so

much to mention the party to whom the credit of introduction was due, as to state a few facts immediately connected with the history of the instrument. Mr. Osborne introduced the instrument into Ireland, Mr. Manning initiated its use among the junior assistants.

'"Mr. Osborne was the first to construct an iron bridge upon the plan of Howe's Patent Truss, several of which he put upon the Waterford & Limerick Railway; and, I believe, he also built and placed upon the same road, the first eight-wheeled, double-truck passenger and freight cars (American plan) that were ever used in Great Britain.

'"Mr. Manning gives us a very entertaining sketch of the history of that first transit, made by Young, of which we remarked that we had in times past made use.

'"'Twenty and odd years ago — when a mere boy — I saw that instrument upon a lawyer's table, and afterwards in a court-room — a dumb witness in behalf of the patentee. Nineteen years ago, after considerable service in tracing the center line of the Washington branch of the Baltimore & Ohio Railroad, it was used in making surveys for the extension of the last-named road, westward from Harper's Ferry, and your humble servant carried and used it at that time in Washington County, Maryland, and in Ohio County, Virginia.

'"'In the last seven years the instrument accompanied me as a duplicate, and was occasionally used upon the location and construction of the Baltimore & Ohio Railroad, through the wilderness, west of Cumberland, and now rests upon its laurels in the office of the Baltimore & Ohio Railroad Co., in Baltimore.

'"'It was *instrumental* in setting the first peg that was driven for the extension of the Baltimore & Ohio Railroad, west of Harper's Ferry; and it was "hard by," and able to do duty, when the last peg was set for completing the track of that road upon the banks of the Ohio River.

'"'In all material points Mr. Young has never been able to improve upon this original work of his hand, but in some of its minor parts he has effected desirable changes such as the tangent screws connected with the clamp of the tripod, the substitution of a clamp and tangent screw for the old rack-and-pinion movement of the two compass plates, the subdivision of degrees into minutes, by an improved graduation of the vernier, etc., etc.

'"'The original instrument had an index for counting the number of deflections made at one sitting; also a small bubble upon the exterior of the telescope, for the purpose of defining a horizontal line, without resorting to the aid of its companion, the ordinary level; but these superfluities were soon thrown aside; and one of its peculiar features was, and is, a vernier, graduated only to *three* minutes.' "

'Mr. Manning but expresses the facts when he says that in all *material* points little change has taken place. The changes

FIG. 7. — INTERCHANGEABLE AUXILIARY.
Used as Side Telescope.

FIG. 8. — INTERCHANGEABLE AUXILIARY.
Used as Top Telescope.

that have taken place have been those called for by peculiar circumstances — modifications which, while retaining the characteristics of the transit, have approached more nearly to the peculiarities of the theodolite. Transits in after years became divided into the two distinct classes, Flat Center, as first introduced, and Long Center, with centers as previously used on theodolite; but it was not for many years that the long center — for accurate work the best construction — became other than the exception. It now is the rule, and the flat center the exception.

'Engineers of the present day, unaware of the actual difference in these two styles, and unacquainted with the circumstances of early introduction of instrument, are apt to treat the flat center with a disrespect it is far from deserving.

'For the same strength, the flat centers are far the lightest. Said an experienced and competent engineer to us, within a few days past, "The first requisite of a transit is lightness and portability." Judged by these requisites, the flat center is the instrument of to-day. But he spoke for his own peculiar branch — railways; and while we are by no means ready to indorse this opinion, we have no hesitation in saying that the circumstances existing at the time of first use of the transit were such that had the instrument been constructed with the long center, its usefulness and general introduction would have been very much retarded. The great peculiarity of the first-made transits was their ability to stand hard usage, and non-liability to get out of order under ordinary usage. The center is a broad metal plate — thick, which it is impossible to bend or injure in any manner, except by wear; the plates were thick, not easily bent, and the spring vernier, in case of bending of plates, followed their motions and allowed the readings to be made sufficiently accurate to continue work. The rack and pinion had nothing that could break, while the tangents, as then constructed, were equally simple. If the standards, by a fall, were bent so that the telescope would not revolve in a vertical plane, the construction was such that with the ax as a screwdriver the standards could be loosened and a piece of paper inserted to correct them.

'In fact, the opinion of the writer, with means of observation and the use of such an instrument, is, *that a flat-centered transit, rack and pinion, and spring vernier, cannot be made totally useless by any accident short of absolute breakage of parts.*

'Not so, however, with the long center. There the least injury to centers or plates ends the usefulness of the instrument for its work, and it can stand comparatively little rough usage without receiving this injury.

'Of the good judgment of the first form of construction, the length of time that many of them have been in use — for some are still doing duty — is the best of evidence. Twenty-five years ago, as rodman, we followed and worked with a flat-center transit that to us then looked old enough to retire upon its laurels. So con-

stant had been its use that its corners — of hard, hammered brass — the edges of its standards, and other parts, had then been rounded in carrying against clothing. Ten years afterwards we followed behind it, on the location of one of our main lines across the mountains, where for a long time it had been the sole available instrument; and one year ago it was in the shop for repairs, the owner still believing that for railway work it had no superior. This instrument was light, weighing between 15 and 16 pounds; had

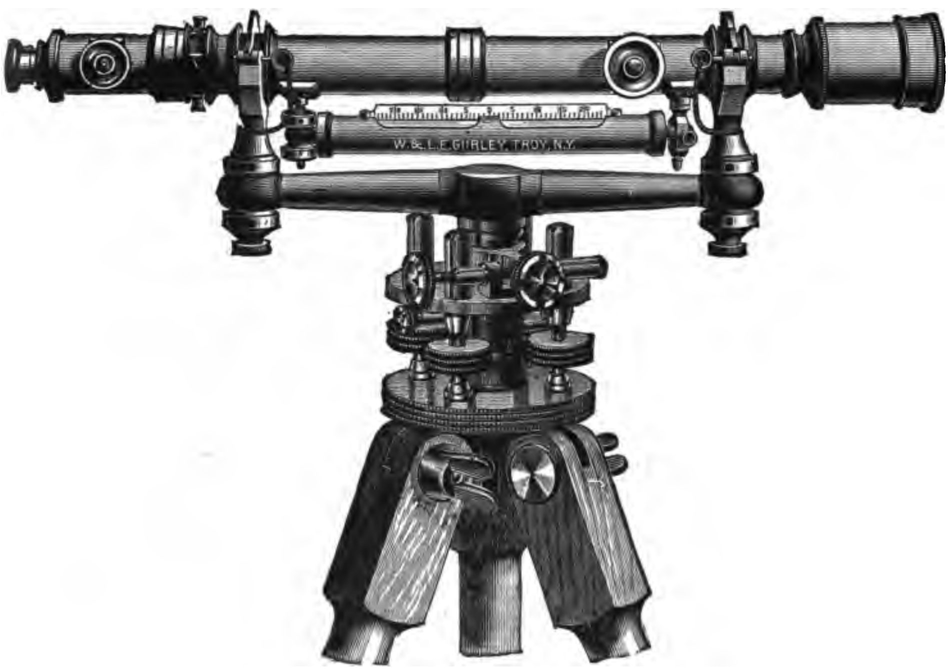


FIG. 9. — WYE LEVEL.

seen at least forty years' service, a large part of the time in the hands of assistants. and in rough, wooded country. We doubt the possibility of a long-centered instrument leading an equally long life.

'While in charge of some railway works, we kept in the office, where there were several assistants, both styles of instruments, and the assistant's choice, in all cases, was for the flat center.

'It is not our intention to argue any superiority in the first

form of transit. It is not the equal, for accuracy and smoothness of motion, of the long center. Its day of universal application has passed and its field of usefulness narrowed; but it yet *has* its field, and the engineer will do well in making selections to give it fair consideration. Our desire is simply to do it justice, and to offer for it a slight defense to our younger engineers, who, having never seen or used it, can know but little of its faults or merits.

'In the transit's early days, no express, on call, drove to the door, receipted for the boxes, and relieved all anxiety, no matter how many thousand miles away nor what obscure point was the destination. Instead of this they had in many cases to be consigned to the top of the stage, or to the Connestoga wagon, unless the destination was near the coast, when the sea became the best route. Thus we find the following extracts, looking at random into the books of shipment:

'"1833. August 13th. Sent, per ship *Chester*, to F. Beaumont, Natchez, care of Florchell & Co., New Orleans.

"1833. August 16th. Sent, per brig *Mohawk*, to Boston, to W. G. Neil, for Boston & Providence Railroad."

'There is no difficulty in understanding why the call was for a transit that nothing much short of entire annihilation would render necessary to send back, over its slow, long, and uncertain journey, for repairs.

'The spread of internal improvements in this country had, at this time, fairly commenced, and with it the demand for the new instrument increased rapidly. So great was this increase, and so much did it outgrow the facilities of manufacture, that the inventor was compelled to send to England an order to have the greater part of a limited number of transits made. This was in 1835, and these were the first transits, or parts of transits, made in England. About three dozen were thus obtained, the more particular parts being made here. They proved far from remunerative; some few were passable, others more troublesome, requiring alterations and repairs; while a fatal fault to a needle instrument (iron in the metal) was found to exist in nearly a dozen.

'Of the latter, most were broken up; several remained in the establishment in an unfinished condition until recently, one of

the last being taken to adorn the monument of a civil engineer, in Laurel Hill Cemetery, Philadelphia.

'The earlier manufacture of the transit instrument was, for want of conveniences, attended with many difficulties. The art of graduation had as yet made but little progress, and the introduction of the transit called for nearer approach to perfection. The first graduating machines were extremely primitive, consisting simply of a circular plate of about 18 inches diameter, upon which degrees and half degrees were marked off, either by mechanical subdivisions or from a similar plate. The one in the establishment of W. J. Young bears the name of "Adams, Maker, London," and consists of such a plate as we have described.

'Such were the means of graduation in 1820. Mr. Young started, as soon as he commenced business, the construction of an engine of 24 inches diameter, worked by the endless screw and treadle; and shortly after the introduction of the transit, commenced another of 26 inches diameter, for finer work, in which a new and important principle of construction for these engines was introduced. A few years afterwards, this same machine was rendered automatic, and is yet doing active duty. About the same time, Mr. Edmund Draper constructed a graduating engine which, among those acquainted with it, has a high reputation for accuracy.

'As transits advanced to perfection, these advances in graduation became necessary. That they were not made at once, but were the result of almost a life of thought, work, and patience, and source of expense, is evident from the fact that from 1821 to 1860, or but ten years before his death, W. J. Young was almost constantly engaged upon the making or perfection of these engines.

'Another serious difficulty arose from want of opticians of ability. The first glasses used were imported principally from England. With the slow communication across the ocean at that period, it was long before an order given could be received; and the purchase of all glasses to be found here of proper size and focal length furnished but a short supply. What was more troublesome was that the next supply differed in size and length from the last. When an inquiry for a larger instrument, or one of different construction, came, the question which determined the practicability of its manufacture was the capability of making the telescope.

'The transit instrument having thus been brought nearer perfection in graduation and optical performance, received but few more changes in construction. The decimal graduation of vernier suggested at an early day by S. W. Miffin, C.E., proved a great advantage in the turning off deflection angles for curves, and was adopted by many, notably by the engineers of Pennsylvania Railroad, all of whose instruments were graduated in that manner.

'The *loose* vernier and arc, for vertical angles, applied by the writer about the year 1850, was an improvement over the much-liable-to-be-injured full circle.

'The shifting staff-head, patented by W. J. Young, in 1858, was another of those little improvements which increase the value of the instrument much.

'The many varied uses to which, from progress of science in this country, the instrument has been called, has brought forth instruments of greater delicacy and different constructions, until to-day, the finest transit of the conscientious instrument maker is a splendid instrument, not surpassed in its performances by the production of any other country.

'Of later minor improvements, some beneficial, some the exploded humbugs of bygone days, we are not now to speak. The profession has other means of discovering them. Our desire is simply to keep from oblivion, the dates and circumstances of introduction of the instrument which has played so important a part in the ever memorable forty-five years of American railroad construction, and which might, perhaps, be lost in the whirl which has been crowding the railroad mind ever forward, leaving it no time to look back to the earlier laborers.

'*Telescopes.* — Telescopes placed upon transit instruments within the past few years have a higher power than was formerly placed upon the generality of these instruments.

'The general demand is for a high power; and those unacquainted with the subject consider the higher power the better telescope. The *power* of a telescope depends upon proportion of focal lengths of object glass and eyepiece; and while in theory *any* power may be given to any telescope, in practice the extent is limited by other *points,* such as effects of aberration, loss of light, and size of field view. With the same object glass *every* increase of power is followed by a decreased illumination, or a decrease of light and a smaller field. These results follow in obedience to

mathematical laws, and cannot be obviated. Science has given certain proportions between power and length of telescopes, and the best opticians of Europe, with their extended experience, invariably follow these proportions.

'The practice in this country of late has been to force the power beyond these bounds; the result is, that while under very favorable circumstances the center of field of view will give a somewhat better definition, it will only do so under favorable circumstances, such as clear atmosphere and strong illumination of the object; and that either the field must be much reduced or objects out of immediate center will not be in focus. In cloudy weather, in lesser light of morning and evening, in the tremulous condition of atmosphere arising from evaporation from the surface of the ground, especially cultivated ground, these high powers all suffer.

'There are purposes, where great definition is so much an object as to supersede all other telescopic requirements, in which these high powers are advisable; but the engineer should understand that in using them that he loses on the other points, and especially remember the exact focusing required of them; otherwise parallax produces a sensible error. For rapid working the exact focusing of high powers is a drawback, a change in telescope being required for almost every small change of distance. Comparison of two telescopes differing widely in power will illustrate this. In the lower powers, in ranging a line, distances between 300 and 400 feet require little if any change, and the same of say 500 and 700, or 800 and 1200; but in higher powers every change of a few feet, until practically parallel rays are reached, requires separate focusing, and if not properly focused are liable to be less distinct than the lower powers.

'The loss of light, even in the best high powers, is what gives an impression of glass being "less distinct" on its first use, for though smaller objects are better defined by it, the impression on its first use is one of cloudiness.

'Fortunately the particular use of engineering instruments requiring definition on but one point at a time allows us to make other conditions of optically good glass subordinate to this one of power to a great extent.

'Inverting glasses are not more powerful, except that from the small space occupied by the eyepiece, they allow for the same

length of telescope a greater focal length of object glass, and thus increase the power.

'They, however, have a much greater amount of light, or greater illumination, and a much larger field. The prejudices of American engineers are against them, but in Europe their merits are almost universally acknowledged, and they are almost the only ones used.'

The Adjustments of the Transit[1]

While every elementary text-book on surveying gives a description of the adjustments, it is thought best to include it in this work, as the uses to which the transit is put underground are so varied and the accuracy required so great.

The adjustments of an engineer's transit are of two kinds: (1) The maker's adjustments, or those which reliable makers give the instrument while it is in process of construction; and (2) the field adjustments, or those which occasionally have to be verified in the field use of the instrument. The latter are, as a matter of course, included in the former, since makers always find it necessary to verify all the adjustments, and deem it an essential requisite of a properly constructed and thoroughly tested instrument, to send it from their hands only when in every respect accurately adjusted for immediate use.

The Maker's Adjustments. — In order that the mathematical conditions of the practical problem of angular measurements in the field may be realized in the instrument itself, it is necessary that the following points of construction and adjustment be accurately attained:

1. The lenses of the objective and of the eyepiece of the telescope truly centered in their respective cells.

2. The optical axis of the system of lenses coinciding with the mechanical axis of the tube, in all the relative positions of the objective and eyepiece, the lenses remaining always at right angles to this axis.

3. The cross hairs, during each observation, in the common focus of the object glass and eyepiece.

4. The vertical cross hair (all other adjustments made) at right angles to the horizontal axis of the instrument.

5. The line of sight at right angles to the horizontal axis, or coinciding with the axis of collimation.

6. The axis of the telescope level lying in the same plane as the

[1] Based upon "Engineers' Manual," Queen & Co.

line of collimation, or not 'crossed' with respect to the collimation plane.

7. The axis of the telescope level parallel with the line of sight.

8. The horizontal axis of the instrument at right angles to the axis of the alidade, or to the axis of the upper plate; and hence (all other adjustments made) the line of sight always lying in the plane which is at right angles to, and passes through the center of, the horizontal graduated circle.

9. The form of the pivots of the horizontal axis the equivalent of true cylinders.

10. The V's or bearings for these pivots, of equal form.

11. The vertical graduated circle at right angles to the horizontal axis of the instrument.

12. The vertical graduated circle and its verniers truly centered with respect to the horizontal axis.

13. The alidade, or upper, plate at right angles to its axis.

14. The axis of the alidade, or upper, plate coinciding with the axis of the lower, or circle, plate.

15. The lower, or circle plate, at right angles to the common axis of both alidade and circle plates.

16. The graduations of the horizontal circle and of its verniers, true and concentric with the common axis of the alidade and circle plates.

17. The zeros of each set of verniers, or reading microscopes, accurately 180° apart, as measured at the respective centers of the graduated circles.

18. The axis of each of the alidade levels at right angles to the vertical axis of the instrument.

19. The pivot of the compass needle coincident with the vertical axis.

20. The zeros of the compass graduations in the same plane as the line of collimation.

21. The magnetic needle perfectly straight.

22. The magnetic axis of the needle coinciding with the axis of form.

23. The magnetic needle adjusted for the magnetic dip of the place of observation.

24. The axis of the suspended plumb bob coinciding with the vertical axis of the instrument.

While it would be difficult and unnecessarily tedious to set

down every adjustment attended to by the maker, the foregoing may be taken as a list of the more prominent ones. Other adjustments peculiar to the accessories of the transit and to special forms of the transit will be referred to in treating of these elsewhere.

The Field Adjustments. — The following practical methods for detecting and correcting the errors of an engineer's transit are given for use in the field. A full explanation of the nature of each error is also made in order that the work of detection and correction may proceed intelligently.

FIRST ADJUSTMENT. — To make the axis of the plate levels perpendicular to the vertical axis of the instrument.

Detection of Error.[1]— Level the instrument carefully both ways, care being taken to make each bubble tube parallel to a pair of plate screws. Turn the telescope through 180° by measuring on the vernier plate. This measurement should be a direct angular measurement on the plate, and not a mere approximation. If the instrument is not in adjustment the bubbles, after this revolution, will no longer remain in the centers of the tubes. This displacement of the bubbles is twice the true error of the instrument. For if $a\,a'$ (Fig. 10) represent the projection on a parallel vertical plane of the bubble tubes, $o\,o'$ the vertical axis of the instrument, the turning through 180° would bring a to a'' and a' to a''', the angles $a''\,o'\,o$ and $a'''\,o'\,o$ being respectively equal to $a\,o'\,o$ and $a'\,o'\,o$. The line KL representing the proper position of the bubble tube, the angle $a'\,o'\,a''$ will therefore be the double error, and cause twice the displacement of the bubbles due to the true error.

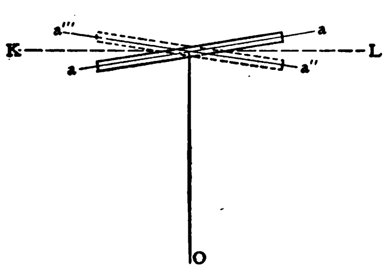


FIG. 10.—PLATE LEVELS NOT PERPENDICULAR TO VERTICAL AXIS.

Correction of the Error. — To correct, bring the bubbles half way back to the centers of the tubes by raising or lowering either end of the tubes, screws being placed there for that purpose. Then level accurately by means of the plate screws.

This process should be repeated several times, as, without extreme accuracy in this adjustment, any attempt to perform the other adjustments is valueless.

[1] After the other adjustments have been made the telescope level can be used to check the plate levels or, in fact, to set up by.

SECOND ADJUSTMENT. — To make the line of sight coincide with the line of collimation, or to make the line of sight perpendicular to the horizontal axis of the telescope.

Detection of the Error. — The direction of the line of sight is determined by two points; the optical center of the object glass, and the intersection of the cross hairs. Of these the latter is movable and is the part whose position is to be corrected.

Set up the instrument, level carefully, and sight (Fig. 11) to some well-defined point, *A*. Reverse the telescope (i.e., turn it over) and sight to *B*. *A* and *B* should be as far distant as possible from the instrument, since the apparent deviation and con-

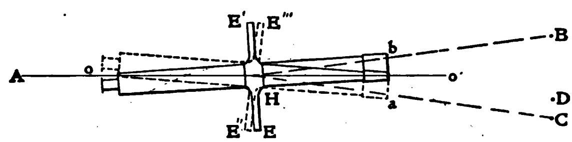


FIG. 11. — LINE OF SIGHT NOT PERPENDICULAR TO HORIZONTAL AXIS.

sequently the accuracy of the subsequent correction increases as the distance. *B H* should be taken equal to *A H*. If the line of sight *oo'* be not perpendicular to the horizontal axis of the instrument *EE'*, *A* and *B* will not be on the same straight line with *H*. To determine whether this is so or not, turn the telescope around on its vertical axis and sight to *A*. The horizontal axis of the instrument now occupies the position *E'' E'''*, the angle *OHE'* of the old position corresponding to *OHE''* in the new, and the angle *OHE* to *OHE'''*. Now reverse the telescope (turn over on horizontal axis); its line of sight will strike this time as far to the left of the line *Aoo'* as it did before to the right, that is, at *C*. The angle *aHO'* represents the doubled error, so also does *E''HE*, since these angles are equal. But the total angular movement from *B* to *C* represents the sum of these angles, and is consequently four times the true error.

Correction of the Error. — To correct, with the telescope pointed at *C*, place a stake at *D*, the distance *D C* being made equal to one fourth *B C*. Move the cross-hair ring by means of the capstan-headed screws placed on the side of the telescope, until the intersection of the hairs cuts the point *D*. This operation is accomplished by screwing both screws at the same time,

the one in and the other out. It should be remembered that an inverting or astronomical telescope does not invert the motion of the cross-hair ring, and hence the screws must be turned so as to move the ring in the *same* direction as that apparently required to produce coincidence. With the usual terrestrial or erecting telescope the screws must be turned so as to move the ring in the *opposite* direction from that which the error apparently requires.

Effect upon Reading of Horizontal Angles. — If the line of sight is not at right angles to the horizontal axis but makes any angle, say $90°-c$, the quantity, c, is the error of the line of sight of the collimation error. The effect of such an error, c, on measurement of horizontal angles is best seen from Fig. 12.

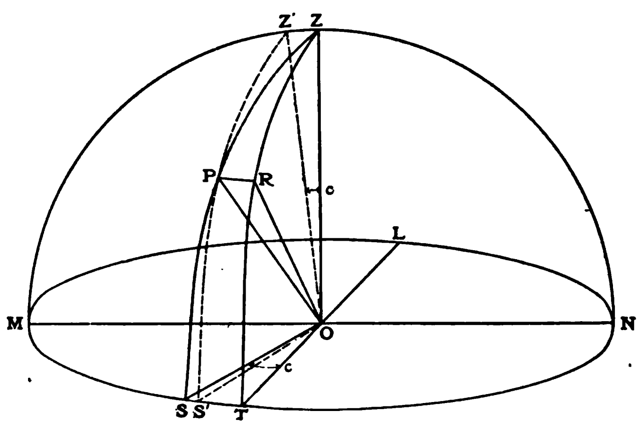


FIG. 12. — EFFECT OF ERROR IN SECOND ADJUSTMENT.

In this figure, MN is the horizontal axis, OZ is the vertical axis, while OZ', OP, and OS' are three positions of the inaccurately adjusted sight axis or line of sight, which makes respectively the equal angles $Z'OZ$, POR, $S'OT$, or c, with the plane ZRT, so that $Z'PS'$ is a parallel to the great circle ZRT.

Let the sight axis be directed to a point P, whose altitude is $PS=h$. Then, if the sight axis were accurately collimated, P would be projected on the horizon at S. But with the error c in collimation it is projected at S'. PR, as the arc of a parallel to MTN, very approximately equals c. For any altitude h, the error c, or PR, projected on the horizon, is ST, or SS' is in excess of the effect of the same error on a horizontal pointing. For varying

altitudes, therefore, the given error consists of a constant part $S'T$ and a variable part SS'. Denoting ST by Z, $S'T$ by c, and SS' by (c), we evidently have from the figure

$$(c) = Z - c$$

and because PR may be assumed as approximately equal to c and is the arc of a parallel to ST.

$$Z = c \sec h \tag{1}$$

and inserting this value in the previous equation, we have

$$(c) = c \cdot \sec h - c \tag{2}$$

which allows the variable collimation error to be computed as a simple function of the assumed constant error c and the altitude h.

The following table, for various assumed altitudes and various assumed values of c, will give a practical idea of the effect of collimation error upon measurements of horizontal angles with the line of sight directed to the given altitude.

TABLE SHOWING EFFECT OF AN ERROR c OF COLLIMATION ON MEASUREMENT OF HORIZONTAL ANGLES

c	Altitude h.								
	1°	2°	3°	4°	5°	10°	20°	45°	60°
10″	0.00″	0.01″	0.01″	0.02″	0.04″	0.15″	0.6″	0′ 4″	10″
1′	0.01	0.04	0.08	0.15	0.23	0.93	3.9	0 25	1′
2′	0.02	0.07	0.16	0.29	0.46	1.85	7.7	0 50	2′
5′	0.05	0.18	0.41	0.73	1.15	4.63	19.3	2 04	5′
10′	0.09	0.37	0.82	1.46	2.29	9.26	38.5	4 09	10′
15′	0.14	0.55	1.24	2.20	3.44	13.88	57.8	6 13	15′

The Practical Deductions from the preceding discussion are:

First. The constant part, $S'T$, of the projected collimation error is eliminated by taking the difference of the two readings for any two pointings, and hence is not ordinarily in question, in measurement of horizontal angles.

Second. The varying part, SS', of the projected collimation error, or *the* collimation error, is also eliminated by taking the difference of any two pointings of the same altitude.

For, representing the collimation error due to two pointings of different altitude, h_1 and h_2, by $\triangle c$, or, what comes to the same, letting $\triangle c = (c)_1 - (c)_2$, we have evidently from equation (2)

$$\triangle c = c\ (sec\ \ h_1 - sec\ h_2),$$

which, for $h_1 = h_2$, becomes zero.

Third. The varying part, SS', of the projected collimation error is also, for pointings of different altitudes, eliminated when the angle between the two points is determined by the principle of reversion, or when the angle is first measured in one position of telescope and then the telescope turned over on its horizontal axis and round the vertical axis, the measurement again made, and the mean of the two measures taken.

For if $\triangle c$ is considered positive in one position of the telescope,

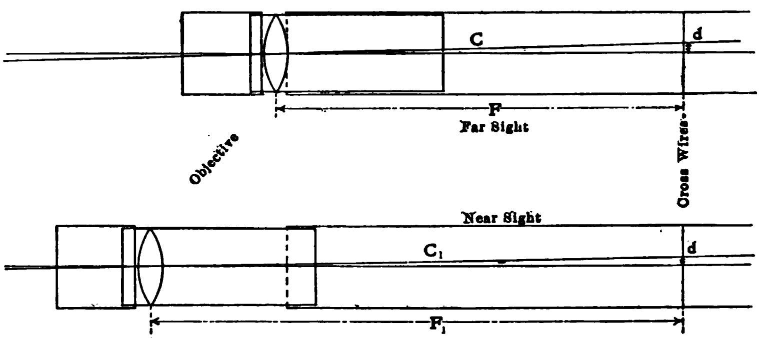


FIG. 13. — EFFECT OF CHANGE OF FOCUS.

it must be considered negative in the reverse position; and hence entering with different signs, it is eliminated by taking the mean of the measures for the two positions of the telescope.

Fourth. From the table it is evident that the collimation error likely to exist is, for low altitudes, negligible even in high-class work. Even for $c = 10'$ and $h = 10°$ the table shows the error less than $10''$. The table also shows the necessity for painstaking collimation, or for proper methods of elimination of the error, when the pointings of the telescope are of any considerable altitude.

When Vertical Wire is Not in Line of Collimation. — There is also a small error introduced when both sights are horizontal. Owing to the change of focal distance when sighting on objects

first far and then near, the angle c is not constant. When sighting on a far object the objective is drawn far in and F is short, say for instance 8 inches. When sighting on a near object (modern mining transits can be sighted on an object only 4 feet distant) the objective is run clear out and F may be as much as, say, 10 inches.

If, now, the angle c be 10 minutes when sighting on a far object, when $F = 8$ inches, then c will become $10'' \times \frac{8}{10} = 8$ minutes when the object sighted is near and F, is 10 inches, or the real error of the reading of the angle measured is $10'' - 8'' = 2''$. This is shown more clearly in Fig. 13.

c = angular error for distant object.
c_1 = angular error for near object.
F = focal distance for far object.
F_1 = focal distance for near object.

$$c = ctg \frac{-1F}{d} \quad c_1 = ctg \frac{-1F_1}{d}.$$

d is constant; F varies inversely with distance of the object sighted, but an angle decreases as its *ctg* increases, i.e., c decreases with nearness of object sighted.

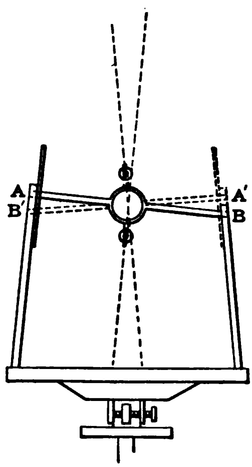
THIRD ADJUSTMENT. — To make the line of collimation revolve in a vertical plane.

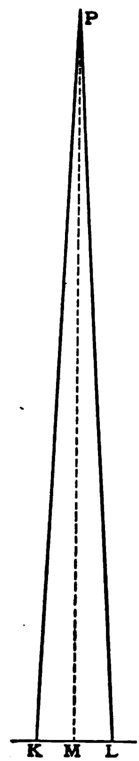
Detection of the Error. — Set up the instrument, and level carefully. Sight to some high object. The top of a steeple is generally most convenient. Depress the telescope and note carefully where the intersection of the cross hairs cuts the ground. Turn the instrument through 180° (this time only approximately) and, reversing the telescope, sight to the same high point, depress the tube again, and again note where the line of collimation strikes the ground. The fault to be remedied is that the horizontal axis of the telescope is not parallel to the plane of the plate bubbles (Fig. 14). Turning through 180° brings the support A to A' and inclines the axis as represented by the dotted line $A'B'$, the angles BOA' or $B'OA$ representing the doubled error, since the line drawn through O parallel to the bubble plane would bisect them both.

The motion of the line of collimation is represented in Fig. 15, P being the high point, K and L the two points on the ground,

M being the middle point which the cross hairs should cut if the instrument were in adjustment.

Correction of the Error. — To correct, therefore, raise or lower one end of the axis *AB* by means of a screw placed in the standard for that purpose, until the line of sight revolves in the plane from *P* to *M*. The reflection in a basin of mercury of the high point





FIGS. 14 AND 15. — HORIZONTAL AXIS NOT TRULY HORIZONTAL.

will suffice to determine the point *M*, and the consequent error *KM* or *ML* be determined without the reversal of the telescope. Instead of a very high terrestrial object a star may be advantageously used in this reflection method.

Error Introduced. — If the horizontal axis of the telescope is not at right angles to the vertical axis of the instrument, but makes an angle $90° - i$, i is the error of the horizontal axis.

In Fig. 16 OZ represents the vertical axis, MN the horizontal axis at right angles to OZ, or in correct position, and $M'N'$ the horizontal axis making an angle i with the correct position. The line of sight will therefore move in the plane $Z'PT$ instead of the

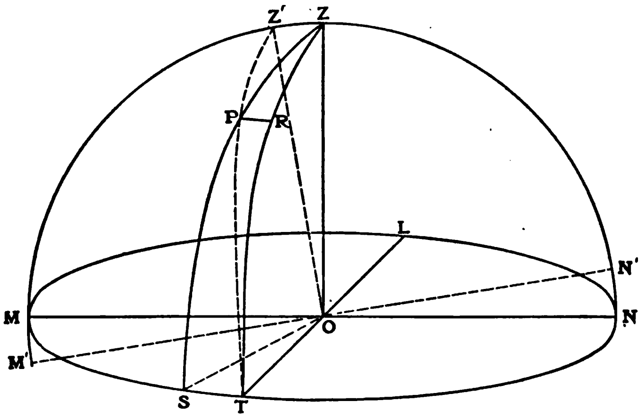


FIG. 16.—THE HORIZONTAL AXIS NOT PERPENDICULAR TO THE VERTICAL AXIS.

plane ZRT, and if directed to P, the deviation PR projected on the horizon will be ST. Let $ZZ'=i$, $ST=$ (i), $TR=h$, and $RZ=90°-h$, then from the figure we have:

$$PR=(i)\cos h;$$
$$\text{also } PR=i\cos(90°-h)$$
$$\text{or, } PR=i\sin h,$$
$$\text{and hence, } (i)\cos h=i\sin h,$$
$$\text{or finally, } (i)=i\tan h, \qquad (3)$$

from which formula the following table may be computed:

TABLE SHOWING EFFECT OF AN ERROR i OF HORIZONTAL AXIS ON MEASUREMENT OF HORIZONTAL ANGLES

i	Altitude h.								
	1°	2°	3°	4°	5°	10°	20°	45°	60°
10″	0.17″	0.35″	0.52″	0.70″	0.87″	1.8″	3.6″	0′ 10″	0′ 17″
1′	1.05	2.10	3.14	4.20	5.25	10.6	21.8	1 00	1 44
2′	2.09	4.19	6.29	8.39	10.50	21.2	43.7	2 00	3 28
5′	5.24	10.48	15.72	20.98	26.25	52.9	1′ 49″	5 00	8 40
10′	10.47	20.95	31.44	41.96	52.49	1′ 46″	3 38	10 00	17 19
15′	15.71	31.43	47.17	1′ 3″	1′ 19″	2 39	5 28	15 00	25 59

The *Practical Deductions* from this discussion are:

First. The effect of the existence of an instrumental error i, or of the violation of the condition $H \perp V$, may be eliminated by the method of reversion observation, already explained in the practical deductions concerning the collimation error, c.

Second. The effect of the error i is also eliminated by taking the difference of the readings for any two pointings of the same altitude. For, if we represent the effective errors for the two altitudes h_1 and h_2 of an error i, by $(i)_1$ and $(i)_2$, and $\triangle i = (i)_1 - (i)_2$, we have evidently from equation (3)

$$\triangle\ i = i\ (\tan h_1 - \tan h_2),$$

which, for $h_1 = h_2$, becomes zero.

Third. This error, i, is of much more serious influence on horizontal angles than the collimation error.

Fourth. In a thoroughly tested and carefully adjusted instrument, and with altitudes less than 5°, this error need not be feared, but with an instrument having any considerable error i, or with pointings of a considerable altitude, the resulting error (i) on the horizontal angle is serious.

Fifth. It is to be borne in mind that in observations like those, for example, required in making the third adjustment, the effective error (i), varies as the tangent of the angle of depression as well as of elevation.

FOURTH ADJUSTMENT. — To make the axis of the telescope level parallel to the line of collimation.

Detection of the Error. — Drive two stakes several hundred feet apart. Set up exactly midway between them and, using the instrument as a level, bring the long bubble to the center of its tube. Sight to a rod held on each stake. The difference of these readings will be the true difference of height between the points, no matter what the error of the instrument may be. For if eo, Fig. 17, represent the position of the telescope, the line of sight will cut the rod at A. Turning the telescope around horizontally while the spirit level ll' still indicates the same horizontal reading, the new position of the line of sight will be $e'o'$ and will intersect the rod set over D at C. $CD - AB$ = true difference of height of points D and B. For, since EF represents the proper position of the telescope, then $FD - EB$ = true difference of height of points, and since S is midway between B and D, the angles which eo and

$e'o'$, the two positions of the telescope, make with EF, being equal, must be subtended by equal distances on the rod, or $EA = FC$, hence adding to FD and EB, we have $(FD+FC)-(EB+EA)=$ true difference of height of points (since this addition does not affect the balance of the equation), or true difference $= CD - AB$, as we stated at first.

Now, clearly, having determined the true difference of height of the points, the instrument must be corrected so as to measure this accurately.

Correction of the Error. — Now set up the instrument over one of the *stakes*, measure the height of the cross hair above the top of the stake, either by direct reference to the horizontal set of screws

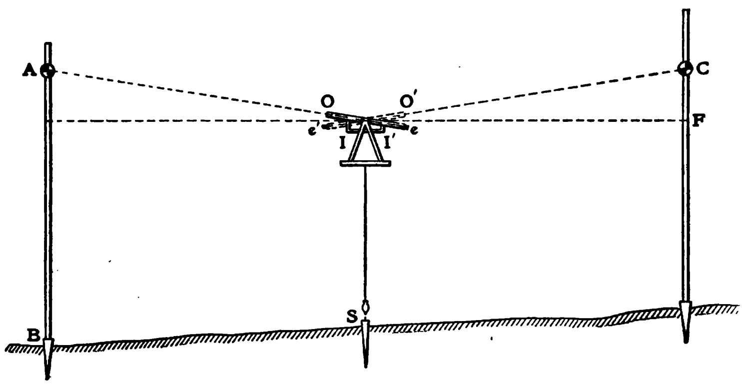


FIG. 17. — TELESCOPE NOT PARALLEL TO LEVEL TUBE.

of the cross-hair ring, or by looking through the objective toward a graduated rod held at a distance of about a quarter of an inch from the eye end, and with a neat lead-pencil point marking on the rod the center of the small field of view. Set the target on the rod to this reading plus or minus the difference of height between the points, according as the point set up over is higher or lower than the second. Now sight to the rod thus adjusted and held on the second stake, and note if the cross hairs cut the target in the center, when the long bubble is in the center of its tube. If not, correct by lowering or raising one end of the level tube by means of nuts placed there for that purpose, until the desired intersection is obtained, the bubble still remaining in the center of the tube. Here the height of the cross hairs above the point over which the instrument is set up is very approximately

independent of any accuracy of adjustment. The entire error of the instrument is therefore shown by its deviation from the true reading as indicated on the rod, by the distance of the cross-hair intersection from the center of the target. Now check up plate levels against telescope level.

FIFTH ADJUSTMENT. — To make the vertical circle read zero when the bubble of the telescope level is in the center of its tube.

Detection of the Error. — This may be done in two ways: (1) By simple inspection; (2) by reversion.

By Reversion. — Sight to some distinct point, note the reading on the vertical circle. Turn the instrument around horizontally half way, reverse the telescope, and sight again to the same point. One half the difference of the readings is the error, it having been doubled by reversion.

Correction of the Error. — The correction is made by moving either the vernier or circle by loosening screws designed for the purpose of permitting circular motion. 'The index error' may, however, be simply noted, and each observation corrected by the required amount. Inspection is the readiest method by which to perform the above adjustment, but when the index error is small and difficult of detection, doubling it increases the accuracy of the correction.

This error, if it be small and the vertical circle have but one vernier, may also be corrected by first setting the circle so as to read zero altitude and bringing the bubble of the telescope level to a zero reading, and then, by the method of the fourth adjustment, moving the cross-hair ring up or down so as to bring the line of sight parallel to the axis of the telescope level.

SIXTH ADJUSTMENT. — To make the vertical cross hair truly vertical when the instrument is leveled.

Detection of the Error. — Set up the instrument and level carefully. Suspend a plumb line from some convenient point. Bring the vertical cross hair into coincidence with it, and note whether the line and hair correspond throughout their entire length. If they do not, the hair is out of adjustment, because, if the instrument be properly leveled the plumb line will be perpendicular to the plane of the bubble tubes.

The same error may be detected by plunging the telescope and noting if the vertical hair passes over some point sighted to, throughout its entire length.

Correction of the Error. — To correct the error the cross-hair

ring must be moved circularly. This is accomplished by loosening the four screws of the cross-hair ring. These screws penetrate the ring a short distance, and are allowed a certain amount of play sidewise by reason of the enlargement of the space through which the screw is inserted. When the screw is tightened the piece just below the head of the screw is clamped fast to the telescope tube. When all four screws are loosened, however, it permits the ring to be turned through a distance limited by the edges of the hole through which the screw is inserted. The vertical hair alters its direction with the turning of the ring.

Error of Deviation of the Vertical Axis of the Instrument from the Vertical. — This is due either (1) to error in the condition $L \perp V$, that is, inaccurate adjustment of the level axis with respect

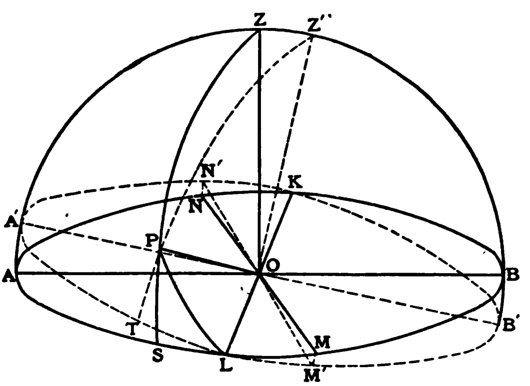


FIG. 18.—THE VERTICAL AXIS NOT TRULY VERTICAL.

to vertical axis; or, (2) to untruthfulness and lack of sensitiveness of the levels; or, (3) to inaccuracy of use of the levels in setting up the instrument.

In Fig. 18 OZ is the vertical, OZ' the vertical axis deviating from OZ by an angle ZOZ', which we designate v. If the axis of sight is directed to P, this point will be projected to T instead of to S; and if we designate AS by u and $A'T$ by u', their difference will be equal to the desired projection error, which we designate (v); that is $u-u'=(v)$. The plane of the circle at right angles to the vertical axis will therefore take the position $A'M'B'N'$ stead of $AMBN$, so that the angle BOB' between the planes is equal to v. The line of sight being directed to P, the horizontal

axis must take the position of $M'N'$, at right angles to OT and approximately to OS, whence the inclination to the true horizontal plane is MOM', which we designate i'. We have now a triangle LMM' right angled at M, whose side $LM=AS$, because AL and SM each equal 90°. But the arc AS is the azimuth of the projected point P as measured from the point of greatest inclination A, and this arc, or its equal LM, we designate u. In the right spherical triangle LMM', $LM=u$, $L=v$, and $MM'=i'$, and hence

$$i'=v \sin u.$$

But an inclination i' of the horizontal axis produced a projected error (i') in measurement of horizontal angles in which, according to the previous article (3),

$$(i')=i' \tan h,$$

$$\text{and therefore } (i')=v \sin u \tan h,$$

$$\text{or } (v)=v \sin u \tan h, \tag{4}$$

where (v) represents the effect of v, for any pointing, as projected on the horizon. For the maximum value of sin u, or I, the formula takes the form

$$(v)=v \tan h,$$

and the table of the preceding section gives the values of the effective error.

The Practical Deductions from consideration of this error are:

First. The error v made in adjusting and setting up the instrument cannot be eliminated by reversion observations.

Second. If we suppose an angle measured between two points of the same altitude we can find the expression for the maximum value of the error $\triangle v$. Let h_1 and u_1 be respectively the altitude and azimuth (as measured from point of greatest inclination of horizontal circle) of the first point, and h_2 and u_2, the same of second point, and the difference between the effective errors (v_1) and (v_2) be $\triangle v$, that is, $\triangle v=(v_1)-(v_2)$; then from equation (4) we evidently have

$$\triangle v=v (\tan h_1 \sin u_1-\tan h_2 \sin u_2). \tag{5}$$

This value attains, for $h_1=h_2$, its maximum in relation to u_1 and u_2 when $\sin u_1=-\sin u_2$, or when $u_1-u_2=\pm 180°$. That is, the error becomes greatest for $h_1=h_2$ when the angle measured

$u_1 - u_2$ is 180°. Under these conditions the above formula (5) becomes

$$\text{Maximum } \triangle v = 2\, v \tan h,$$

or the greatest error $\triangle v$ arising from the error v in verticality of axis will, for a straight angle between two points of the same altitude, be just double the values set down in the table as given.

Third. It is evident that for altitudes less than 5°, and with good levels properly adjusted and care in setting up, no appreciable error need be feared, even in high-class work.

A few general inferences to be drawn from the foregoing discussion of the axial errors c, i, and v, may be of practical use.

First. If we measure horizontal angles with an engineer's transit whose collimation error is c, error of horizontal axis i, and whose vertical axis has a deviation of v from the vertical, the three effective errors (c), (i), (v), may combine in a total (s), so that for a single pointing

$$(s) = (c) + (i) + (v),$$

and if $\triangle s$ represent the total error made in measuring an angle, or for two pointings,

$$\triangle s = \triangle c + \triangle i + \triangle v,$$

or reproducing their values,

$$\begin{aligned} \triangle s = c\ (\sec h_1 - \sec h_2) + i\ (\tan h_1 - \tan h_2) \\ + v\ (\tan h_1 \sin u_1 - \tan h_2 \sin u_2) \end{aligned} \qquad (6)$$

Second. From this equation (6) it becomes evident that it is of importance to choose points nearly of the same altitude if we would by reversion eliminate all instrumental errors eliminable.

Third. Only the collimation error c and the error of the horizontal axis i can be eliminated by reversion.

Fourth. Since the error of verticality of axis v can become larger than any other of the errors, and can also have a more serious result on the measurement of horizontal angles, it requires special attention. The error v, as already stated, depends not only on care in the use of the levels in setting up, but on their proper adjustment, and on their truthfulness and sensitiveness as well.

The Effect of the Axial Errors on the Measurement of Angles

of Altitude. — Having devoted considerable space to the consideration of the effect of small errors of direction of the three principal axes upon the measurement of horizontal angles, we have now briefly to speak of their effect on measurement of angles of altitude. This subject has been rather carefully investigated by Dr. W. Jordan in his inimitable "Handbuch der Vermessungskunde," Vol. II, and we give here as a matter of considerable interest the general result of a cumbrous mathematical discussion.

For a fairly adjusted altazimuth instrument, and for vertical angles not exceeding 45°, the effect of the usual small errors is altogether inappreciable. For angles of greater altitude than 45°, and when extreme accuracy is required, greater care than usual must be taken with the adjustments. It is to be noted, however, that now we speak only of extreme accuracy and of instruments reading vertical angles to seconds of arc. For a total error of the axes of 10′ the sum total of effective error on a vertical angle of 45° is only 0.89″, of 60° only 1.51″, and for a total error of 30′ for vertical angle of 40° it is only 7.86″, and for 60° only 13.60″.

Therefore, even in the use of a fine geodetic instrument, the three axial errors do not, with reasonable precautions, produce any error in measuring angles of altitude less than 60°. Of course, in the use of the engineer's transit, axial errors produce an entirely inappreciable effect on measures of moderate angles of altitude, and are not in question.

It would, however, be an entire misconception to suppose that, since the axial errors do not have an appreciable influence in the measurement of vertical angles, no errors are, therefore, to be feared in such measurement. The *constant* errors, such as the errors of graduation and eccentricity of the circle, and particularly the index error and the error of the level lying in the same plane as the circle, are the ones requiring closest attention. Their elimination can be accomplished only by special methods of work and proper instrumental adjustment and design.

Relative Value of the Adjustments. — For pure transit work — by which we mean the running of straight lines, the measuring of horizontal angles, and the like — the first three adjustments are the most important. The fourth and fifth refer to the instrument when used as an engineer's level, while the sixth, though classed with the first three, is by no means essential. Indeed, this adjustment should be seldom made, inasmuch as its performance

is liable, by moving the cross-hair intersection eccentrically, to displace the second and third, which have already been performed. Should an adjustment of the vertical hair, however, become necessary, the second and third must be tested again so as to insure their non-disturbance. The verticality of the hair, though not absolutely necessary for accurate work, is exceptionally convenient for determining the true perpendicular when only a small portion of a rod sighted to can be seen. Frequent tests of the vertical hair are useful, but its adjustment is unwise unless followed by a readjustment of the instrument in regard to the line of collimation.

General Remarks on the Adjustments.—It is well to note that all of these adjustments, except the fourth, can be performed while the instrument still remains in one position. The fourth being entirely independent of the rest may be left until the last, and indeed is sometimes entirely omitted, as the use of the transit as a level is comparatively rare, except in mine work where it almost always replaces the level.

The great fault of young surveyors is to blame inaccuracies in their work upon a faulty construction of the instrument. For this there is no excuse. Errors may arise from three causes: (1) Errors in, or damages to, the parts of the instrument; (2) insufficient adjustment, and (3) carelessness in setting up or in sighting. The last are by far the most probable causes of inaccuracies in work, and, if the adjustment be unsatisfactory, the surveyor has no one to blame but himself, while errors in the instrument can always be detected by the refusal of the instrument to respond to repeated tests while being adjusted. In the latter case, the only remedy, beyond obtaining a new instrument, is to note carefully what species of errors are likely to occur, and so to handle the instrument as to avoid them as far as possible.

A wide and nearly level stretch of country is by all means preferable for the performance of the adjustments. The sights taken, except those in the fifth and sixth adjustments, should be as long as possible, so that the ensuing apparent error may be greater.

After the surveyor has used his instrument for some time, he may be sufficiently competent to judge of its accuracy. Until then the instrument should be tested at least once a week, if not more frequently. If he should find the instrument one of accuracy and great permanency of parts, less frequent adjustments

may be made. Adjustments should always be made if the instrument suffers a fall, or if the surveyor has reason to believe that a severe jar has happened.

The foregoing methods, while essential to the proper testing and use of the transit, are intended only as instruction in practical field adjustments, and these do not take the place of the permanent adjustments given by makers, although they are to some extent a test of the latter.

The Errors of Eccentricity and of Graduation. — Having treated the axial errors, we still have to consider those errors which are due to: (1) the eccentricity of the telescope; (2) the eccentricity of the circle; (3) the eccentricity of the verniers, and (4) the inaccuracies of graduation.

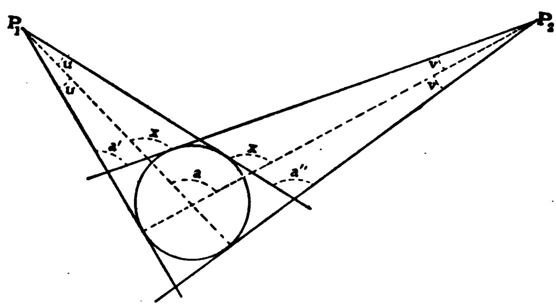


FIG. 19. — ECCENTRICITY OF THE TELESCOPE.

The Eccentricity of the Telescope. — Assuming, in the first place, that there is no eccentricity of the circle or of the vernier, there may still be an eccentricity of the telescope on account of the line of sight not being mounted directly over the center. In Fig. 19 the eccentricity of the line of sight of the telescope is represented by the radius of a circle conceived as described about the center, C, of the circle. All lines of sighting will be tangent to this circle. P_1 and P_2 are two points to which the eccentrically placed telescope is in turn directed, and between which it is intended to measure the angle. The angle a represents the true angle, while a' and a'' represent the angles measured with two positions of the eccentric telescope. A simple inspection of the figure gives us the following relations:

$$a + v = x = a' + u \qquad a + u = y = a'' + v$$
$$a - a' = u - v \quad (1) \qquad a - a'' = v - u \quad (2)$$

$$a'' - a' = 2\ (u - v) \quad (3) \qquad a = \frac{a' + a''}{2} \quad (4)$$

If the respective distances of P_1 and P_2 from the center are d_1 and d_2 and the eccentricity or radius of the small circle of the figure is represented by e, the angles of u and v may be expressed in seconds as follows:

$$u = 206{,}265\frac{e}{d_1} \quad v = 206{,}265\frac{e}{d_2} \qquad (5)$$

Inserting these values in equation (1) we have:

$$a - a' = 206{,}265e\left(\frac{1}{d_1} - \frac{1}{d_2}\right) \qquad (6)$$

Inspecting this equation we see that when d_1 and d_2 are equal to each other, $a - a' = 0$, or there is in this case no correction to be applied for eccentricity of telescope. We also note that $a - a'$ increases with e and with the difference between d_1 and d_2.

Assuming numerical values for e, d_1 and d_2, we may compute the value of $a - a'$. Let, for example, $e = 0.005$ in., $d_1 = 20$ ft., and $d_2 = 120$ ft.; then inserting these values in (6) we find $a - a' = 3.5''$. It is thus seen that when an important angle is to be measured the error of eccentricity of the telescope may become sensible, and the observations should be conducted so as to eliminate the error.

It is, however, also seen from equation (4) that a mean of two observations with telescope in different positions, direct and transited, gives the angle free from this error.

Therefore, to eliminate error of eccentricity of telescope, read the angle in one position of the telescope; then transit the telescope and read the angle again, and take the mean of the two readings. This rule applies to all engineers' transits, no matter how distant from the center of circle the telescope may be, and hence also suggests how the eccentrically placed telescopes of mining transits may be used for accurately measuring horizontal angles.

The Errors of Eccentricity of the Circle. — The errors pertaining to the graduated circle are of four kinds: (1) The error arising from the non-coincidence of the center of the graduated circle with the center of rotation, or the error of eccentricity of the

circle; (2) the error arising from the non-intersection of the center of rotation by the straight line joining the zeros of the verniers or microscopes, or the error of eccentricity of the verniers or microscopes, due to their zeros not being exactly 180° apart, as measured at the center of the circle; (3) errors due to faulty graduation; (4) errors due to inaccurate estimate in reading the verniers or microscopes.

The error of eccentricity of the circle may be investigated as follows: In the accompanying Fig. 20, let C be the center of the

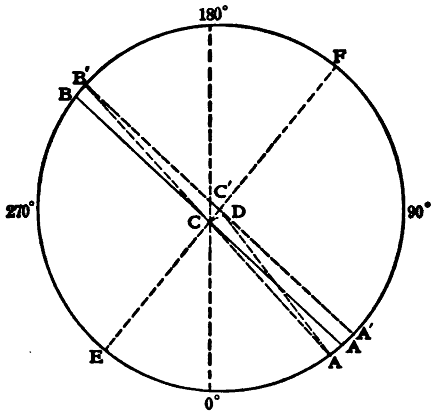


FIG. 20. — ECCENTRICITY OF THE CIRCLE.

alidade, C' that of the circle, CC' the eccentricity, e, and $A'A''$ or $2\,AA'$ the effectible error, ϵ of the eccentricity. Let AB be a straight line joining the zeros of the verniers or microscopes; A the reading of vernier A, B of B, A' the true reading of vernier A, B' the true reading of vernier B. Then assuming that by careful centering of the instrument e has been made very small, the arc AA' may be regarded as equal to the perpendicular CD; and, therefore, representing the arc $EO°$ by E and $0°A'$, as already stated, by A', or the angle $EC'A'$ by $(E+A')$, and representing the radius $C'A'$ by r and 206,265″ by s we have, from the triangle $CC'D$, the following expression:

$$AA' = \frac{es}{r} \sin\,(E + A')$$

But since sin $(E+A')$ and sin $(E+A)$ are sensibly the same we may write

$$AA' = \frac{es}{r} \sin\,(E + A) \qquad (1)$$

If we now allow B to coincide with B' the vernier line of the alidade will lie in the direction $B'A''$ and the effective error due to the eccentricity of the circle will be the arc $A''A' = 2\ AA'$ = the central angle, ε. We have, therefore, finally the following expression for the error due to eccentricity of the circle:

$$\varepsilon = \frac{2\,es}{r} \sin\,(E + A) \tag{2}$$

This equation shows that for the direction EF, when $\sin\,(E+A)=0$, the error ε becomes zero, and that for $(E+A) = \pm 90°$, $e = \frac{\pm 2\,es}{r}$; which is the maximum value for the error due to the eccentricity of the circle.

It is also evident that from $(E+A)=0°$ to $(E+A)=+180°$ a positive series of ε results, and from $0°$ to $-180°$ a negative series of ε. Hence, if but *one* vernier is read in a given position of the telescope, the telescope then transited and directed to the same object, and the *same* vernier read, the mean of the two readings will eliminate the eccentricity. For it is clear that the line of the verniers will in each case make equal angles with the line of zero eccentricity, EF, and hence ε have the same value with opposite sign. In other words, since in equation (1) $\sin\,(E+A)$ will be positive, and $\sin\,(E+A+180°)$ negative, ε will have equal values of opposite signs, and, therefore, in a mean of values will disappear.

We may also apply equation (1) to the readings A' and B' and write:

$$A' = A + \frac{es}{r} \sin\,(E + A) \tag{3}$$

$$B' = B + \frac{es}{r} \sin\,(E + B) \tag{4}$$

By taking the mean of these two readings as thus expressed, we get:

$$\tfrac{1}{2}\,(A' + B') - \tfrac{1}{2}\,(A + B) = \frac{es}{r} \sin\,(\tfrac{1}{2}\,(A + B) + E)\cos\tfrac{1}{2}\,(A - B),$$

whence we see that the difference between the mean of the true readings and the mean of the vernier readings decreases as $(A-B)$ approaches $180°$; and when $(A-B)$ exactly equals $180°$, or when the verniers are rigorously $180°$ apart, this difference is nil. The mean of the readings of two verniers of microscopes which are

180° apart, therefore, completely eliminates the error of the eccentricity of the circle.

In order to comprehend the effect of even a small displacement of the center, let us from equation (2) take the maximum value of ε or

$$\text{Maximum } \varepsilon = \frac{2\,es}{r}$$

and assume $e = 0.0003$ in. and $r = 3.0$ in. Then we have:

$$\text{Maximum } \varepsilon = \frac{2 \times 0.0003 \times 206265''}{3} = 41.25''$$

If e had been as great as 0.003 in., the maximum error of eccentricity would have been 6′ 52.5″.

This fully illustrates the importance of three things: (1) Correct designs of the axes or 'centers' of the instrument; (2)

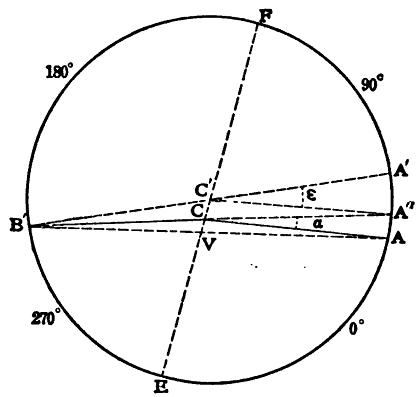


FIG. 21.—ECCENTRICITY OF THE VERNIERS.

care in adjusting circle for eccentricity; (3) the reading of both verniers or microscopes in the higher classes of work.

The error of eccentricity of circles, as here treated, is really made up of two mechanical errors, viz.: (1) inaccurate centering of the circle on its axis of 'center,' and (2) ellipticity of the 'centers' themselves. Moreover, there arises in some designs of 'centers,' a wear of 'centers' which produces a serious eccentricity and which cannot be remedied mechanically except by furnishing the instrument with new 'centers.'

The Error of Eccentricity of the Verniers. — We have hitherto assumed that the zeros of the verniers or microscopes are exactly

180° apart. This may not be the case; and if it is not, we have what may be termed eccentricity of the verniers. The eccentricity of the verniers is the perpendicular distance between the center of the alidade and the straight line joining the zero of the verniers, and is in Fig. 21 represented by CV. The effective error it produces is a *constant* one, represented by the angle a. The effective error of eccentricity ε, is, on the other hand, as already shown, a *variable* one. If, then, the zeros of the verniers or microscopes are not accurately 180° apart, but make an angle of $180° + a$ so that, the eccentricity of the circle for the moment out of question, $B' = A' + 180° + a$; and we may then find from equations (3) and (4) for the entire difference of reading between the two verniers, or $B - A - 180° = \delta$.

$$\delta = a + \frac{2\,es}{r}(\sin E + A). \qquad (5)$$

Considering the alidade turned from its 0° position respectively through the angles 90°, 180°, and 270°, we would have for these four respective values of A the following values of δ:

$$\delta_0 = a + \frac{2\,es}{r} \sin E \qquad (6)$$

$$\delta_1 = a + \frac{2\,es}{r} \cos E \qquad (7)$$

$$\delta_2 = a - \frac{2\,es}{r} \sin E \qquad (8)$$

$$\delta_3 = a - \frac{2\,es}{r} \cos E \qquad (9)$$

whence we find

$$a = \frac{\delta_0 + \delta_1 + \delta_2 + \delta_3}{4} = \text{the mean of all the } \delta\text{'s}. \qquad (10)$$

$$\frac{4\,es}{r} \sin E = \delta_0 - \delta_2 \qquad (11)$$

$$\frac{4\,es}{r} \cos \mathrm{E} = \delta_1 - \delta_3 \qquad (12)$$

which determine a and both e and E.

We also see from equations (6) and (8) that

$$\delta_0 = a + \varepsilon, \text{ and } \delta_2 = a - \varepsilon$$

$$\text{whence } a = \frac{\delta_0 + \delta_2}{2} \text{ and } \varepsilon = \frac{\delta_0 - \delta_2}{2}$$

The objection to the use of the last two formulas for determining a and ϵ are that but two differences are employed, and hence errors of observation and of graduation may make the result uncertain. The only complete method for determining a and ϵ, free from complication with errors of graduation and observation, is to determine a large number of δ's for different direct and reversed positions of the alidade, and then treat the results of the observations according to the well-known method of least squares. For such treatment of the subject our readers are referred to standard treatises on practical astronomy and geodesy. Equations (10), (11), and (12), however, enable us for many practical purposes to derive fairly reliable values of a and ϵ by simply making four sets of observations, at intervals of 90°, of the differences of the vernier or microscope readings.

The Errors of Graduation. — The errors of graduation, unless of the coarsest sort, cannot be investigated until the effect of eccentricity of the circle and of the vernier has been ascertained. After determining the value of the eccentricity of the circle and computing its effect on the division whose graduation error is to be found, the outstanding differences, allowing for the constant deviation of the verniers from the required 180°, are to be attributed to graduation and observation errors. The errors of graduation are divided into two classes: (1) Those which are of a periodic character, and (2) those which are of an accidental character. The former depend upon slow changes in the temperature of the engine during graduation, or in the condition of the cutting tool. The latter are not dependent on known conditions, and being as likely negative as positive, are classed as accidental. It is usually found in well-graduated circles that the major errors of graduation are of the first class and may be expressed as a periodic function of the varying angle.

Instead of using the distance apart of the two vernier zeros as the standard angle, the length of the vernier may be used as a test when successively applied round the circle, and read by means of the excess graduations of the vernier. The effect of the eccentricity of the circle on the length of the vernier must, in this case, be computed and duly allowed for before errors of graduation as such can be noted. For a complete discussion of this subject we refer the reader to the "Vermessungskunde" of Jordan, and to the treatises on practical astronomy of Chauvenet, Brunnow, and Sawitsch.

The Errors in Practical Work. — The foregoing discussion of the axial and circle errors, aside from its value in suggesting points of construction and adjustments of special importance to accuracy of work, should also afford many a hint to the practical engineer. The limited space does not permit us to state either the special features of instruments or the special programmes of work which are in the different cases required to avoid and eliminate all the errors. And yet we may not better close this review of the errors than by drawing attention to several points of caution to be exercised in the three most usual forms of work with the transit, viz., the measurement of vertical angles, the laying out of straight lines, and the measurement of horizontal angles.

Vertical angles have their zero in the horizon, and this zero must be physically determined by a level lying in a plane parallel to the graduated circle on which the measurements are to be made. This level, whether it be a plate level, the telescope level, or a special level attached to the vernier arm, should not only (1) lie in a plane *parallel* to the measuring circle, but (2) should have a sensitiveness comparable to the fineness of the reading on the circle, and (3) should always, in an observation, be adjusted to zero position of bubble, or else be read for the small deviation of the bubble. If the telescope level is used, the vertical angle is simply the difference of readings on the circle for the zero position of the bubble and for the pointing.

The error of vertical axis, or the deviation of this axis from the vertical, may affect the measurement to the whole amount. Both the error of adjustment of the plate level and the index error can be eliminated by striking the mean of the measures of the angle taken with the telescope, both in the direct and in the reverse, or transited position, provided the alidade is carefully releveled after being revolved 180°. The errors of eccentricity are eliminated by reading both verniers or microscopes, if there be two. Transiting and two verniers, however, require a complete circle. For an arc of a circle with one vernier, the adjustments must be relied on. The eccentricity may, for small angles, be considered *constant*; and, if the 'fourth adjustment' has been accurately made, it is eliminated by taking the difference of the readings for bubble at zero and for the pointing. The graduation errors can only be eliminated by using an entire circle, capable of being shifted on its axis. The method of reiteration of the angle may then be employed.

Straight lines can be prolonged accurately only with good instruments and the most careful attention. Here the secret of the elimination of errors is so to arrange the programme of work as to distribute the errors symmetrically with respect to the proposed line. If a circumpolar star is observed for the direction of the meridian it is therefore important that the observations, both as to number and character, be arranged symmetrically with regard to the time of transit, or the time of elongation, as the case may be.

If the pointings for a line are all horizontal, and the line is to be prolonged by transiting the telescope, or turning it over on its horizontal axis, the constant collimation error will enter with double its value. If one of the pointings is at an angle, as in the case of determining the direction of a circumpolar star, the errors of collimation, of the horizontal axis, and of verticality of the vertical axis may all enter the result. Particularly would the error of verticality, due to the level at right angles to the line, be serious, and necessitate attention to the sensitiveness, adjustment, and reading of the level lying in that direction.

A line may be prolonged so as to eliminate all these errors by setting up over the forward point, leveling cross level, bisecting rear point, transiting telescope, locating the required point, and then revolving the alidade 180° and repeating the operation, and taking the mean position between the two located points as the true required point.

Horizontal angles, including the horizontal straight angles just referred to, are those most frequently measured in practical work, and the errors to which they are liable have, therefore, been fully discussed.

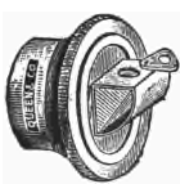


FIG. 22. — PRISMATIC EYEPIECE.

Auxiliary Telescopes. — When the line of sight is highly inclined, the main telescope of the transit becomes useless, owing to interference with the plates of the transit. Several different devices are used to surmount this obstacle. When the sight is downward, the main telescope cannot be used at all, but if the sight be upward, the main telescope can be used if a prismatic eyepiece (Fig. 22) be inserted. This little attachment is made by every engineering-instrument company and is very handy for several purposes. By means of it the transit man looks along a line at right angles to the axis of the

telescope instead of longitudinal to it. This device does not, however, furnish any aid for downward sights.

For this purpose, an auxiliary telescope must be used. These are principally of two kinds; the top telescope attached above

FIG. 23.—MINING TRANSIT.

the main telescope, or the side telescope attached to the end of the horizontal axis of the main telescope outside the standard. The solar compass may be forced to do service as an auxiliary

telescope, but its use is objectionable and but few mine surveyors possess one.

The Top Telescope. — The top telescope (Figs. 4, 8, 23) is fastened rigidly to the main telescope by means of one or two bars long enough to cause the line of sight of the top telescope to clear the horizontal plates when the main telescope is placed in a vertical position. These bars, if two are used, are usually brazed to the top telescope shell by the manufacturer, and attached to the main telescope by means of nipples and coupler nuts. The manufacturers make all light mountain transits with the nipples so that the top telescope may be used if desired, and old transits, if sent to the manufacturer, may have the attachments fitted to them.

The adjustments of the top telescope are very simple. The manufacturer adjusts the top telescope during its making, so that the axes of the two telescopes are parallel and in the same plane. The positions of the objective and eyepiece can be changed only by the manufacturer. The only adjustments for the transit user are those of the cross hairs. First, the line of sight must be in the same plane as that of the main telescope; second, the lines of sight must be parallel, and third, the cross hairs must be truly horizontal and vertical. The first is accomplished by sighting upon a plumb-bob string with the main telescope and adjusting the vertical cross hair of the top telescope until it coincides with the string. The mounting of the single-stem top telescope has a special arrangement for the adjustment to a vertical plane. To secure parallelism of the lines of sight of the two telescopes, two parallel horizontal strings are fastened up at a distance of 100 feet or more, so that the perpendicular distance between the strings is equal to the perpendicular between the axes of the two telescopes. The main telescope is sighted upon the lower string and the horizontal cross wire of the top telescope is raised or lowered until it coincides with the upper string. The cross hairs are brought into true vertical and horizontal positions during the previous adjustments by sighting on vertical and horizontal strings.

When sighting on a point with the top telescope the horizontal angle is not affected, and is read direct from the horizontal circle, but the vertical angle must be corrected.

In Fig. 24, R is the distance between the lines of sight, *md* is the measured distance, *va* is the vertical angle as read from the vertical circle and a is the amount by which it must be

corrected to give the true vertical angle. This angle α is evidently the angle whose sine is $R/m\ d$. Therefore the true vertical angle equals $V\ A \pm R/m\ d$. When the angle is below the horizontal, the correction is to be subtracted, when above it must be

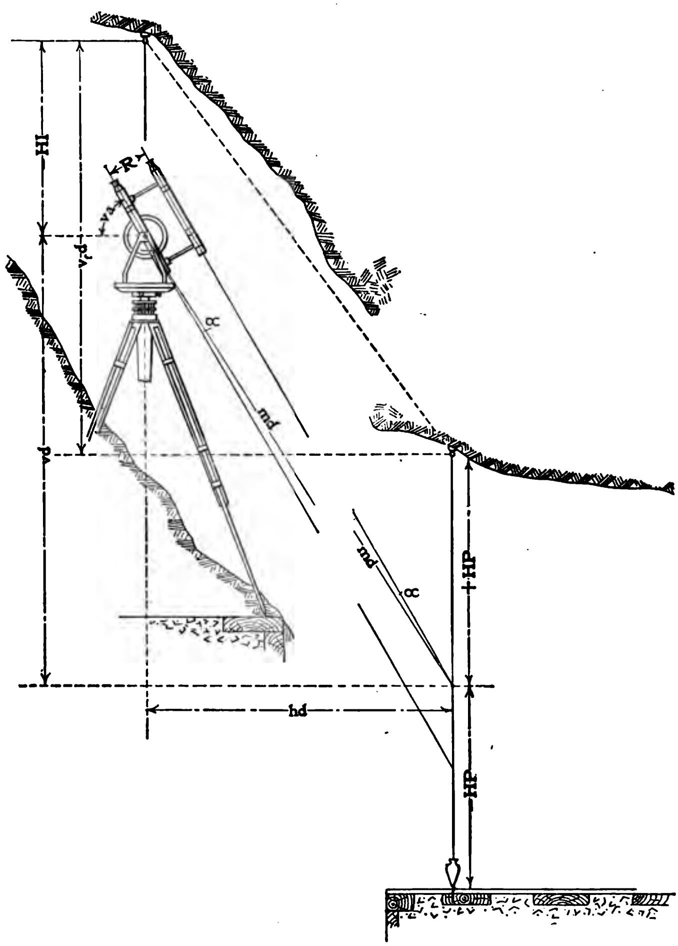


FIG. 24. — TOP TELESCOPE: ELEVATION.

added. This is easily remembered, for the sign of the angle is also the sign of the correction.

The Side Telescope. — The side telescope answers the same purpose as does the top telescope. It clears the plates when

pointed vertically. Being screwed to an extension of the horizontal axis of the main telescope, outside of the standard, it can be attached only to instruments made for that purpose.

The adjustments of the side telescope are practically identical with those of the top telescope. The maker fixes the position of

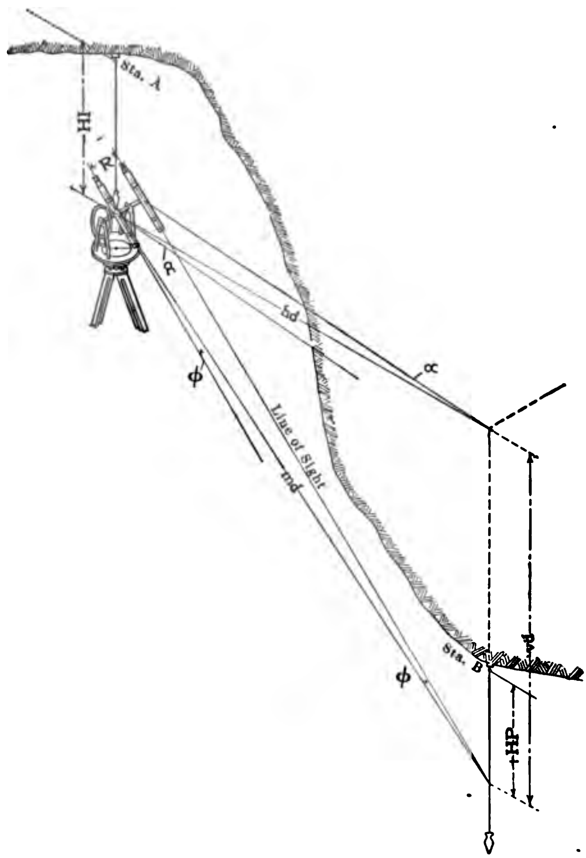


FIG. 25. — SIDE TELESCOPE: ISOMETRIC PROJECTION.

the auxiliary telescope so that the axes of the two are parallel and in the same horizontal plane. The field adjustments are those of the cross hairs only.[1] The lines of sight are made parallel by sighting the telescopes upon two plumb lines whose distance

[1] This is not true of some auxiliaries recently put upon the market.

apart equals the distance between the centers of the telescopes. The horizontal wires are made to lie in the same horizontal plane by sighting upon a horizontal line.

When sighting a point with the side telescope its angle of elevation is read direct from the vertical circle, but the horizontal angle must be corrected.

In Fig. 25, R is the distance between centers of the telescopes, and is the measured distance; hd is the horizontal distance, vd the vertical distance, va the vertical angle, and a the amount by which the angle, as read from the plates, must be corrected.

$$\text{Sin } a = \frac{R}{hd}, \text{ but } hd = md \cos va$$

$$\text{Then } \sin a = \frac{R}{md \cos va} \text{ or}$$

$$a = \sin^{-1} \frac{R}{md \cos va}$$

$$\text{Or, } a = \theta \frac{1}{\cos va} \qquad \text{Now } \theta = \sin^{-1} \frac{R}{md}$$

Substituting this value for θ

$$a = \sin^{-1} \frac{R}{md \cos va}, \text{ as before.}$$

As the sine and tangent of small angles are approximately equal, the formula $a = tg^{-1} \dfrac{R}{md \cos va}$ may be used; and indeed, if, as is most commonly done, the distance measured be from point sighted to the center of the end of the horizontal axis of the main telescope, the formula is theoretically correct.

If the side telescope be on the right side of the instrument, the correction must be added to the angle read from the plates to secure the true azimuth of the point sighted; if on the left side of the instrument, it must be subtracted. By sighting a point with, first, the telescope upon the right side, and then again with it upon the left side (by revolving and plunging) two angles are read which are evidently each in error by the amount a, or the difference between the two readings is 2 a. Halving this amount and adding it to one reading, or subtracting it from the other, gives the true bearing. The value of a can probably be obtained

with greater accuracy by this double reading than by the formula; and besides, the reversed reading eliminates any error which may be introduced by the nonadjustment of the instrument.

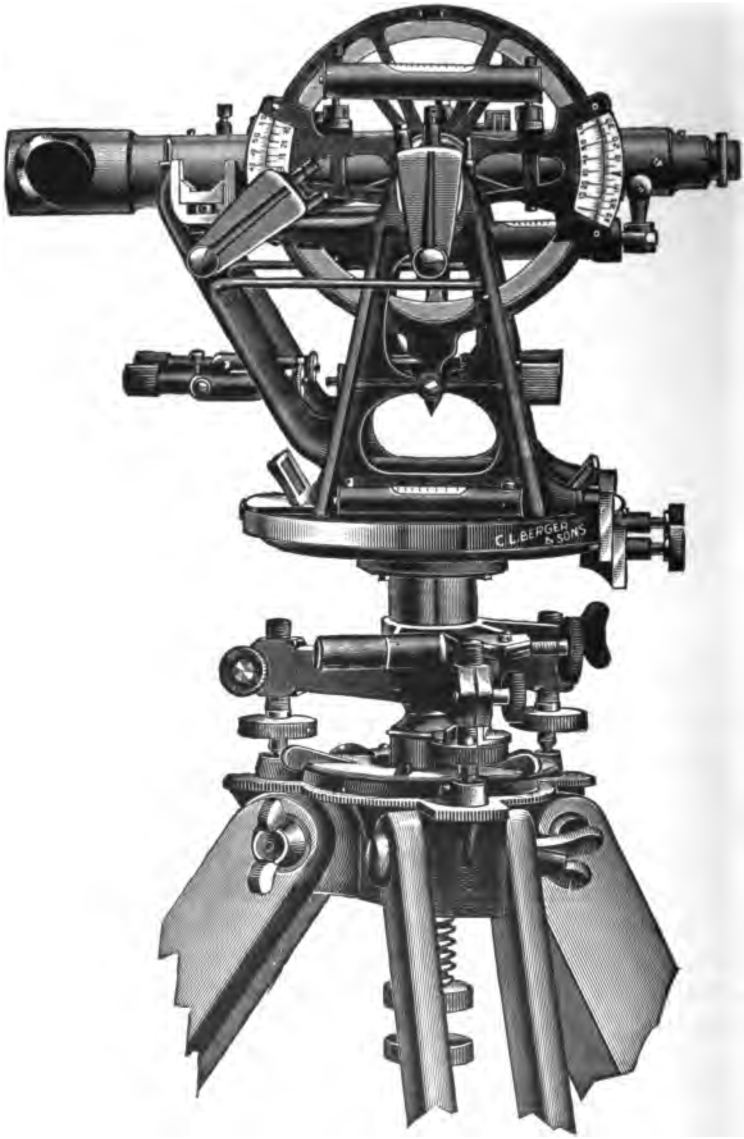


FIG. 26.—TRANSIT WITH DUPLEX TELESCOPE BEARINGS.

Besides the ordinary top and side telescopes, some of the instrument makers are putting an interchangeable auxiliary telescope on the market. This screws on to a single standard

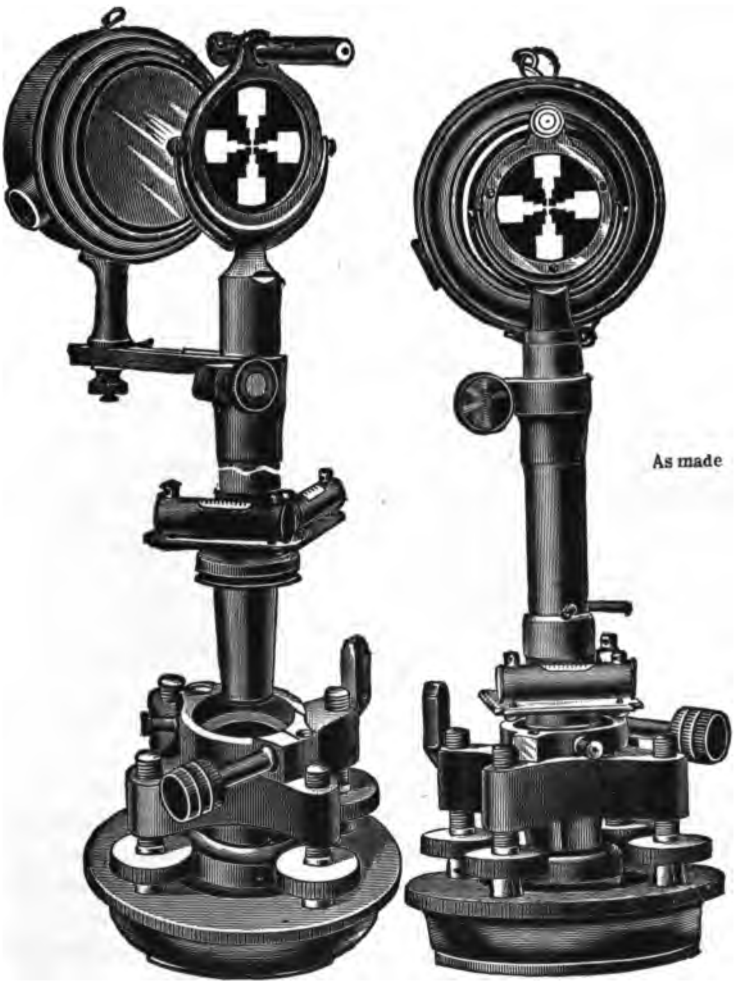


FIG. 27. — LAMP TARGETS.

above the main telescope as a top telescope, or upon the end of the horizontal axis as a side telescope.

Besides the type mechanism for auxiliary telescopes as ex-

plained above, there are nearly as many variations and improvements as there are makers of surveying instruments.

Transit with Inclined Standards. — The novelty in this mining transit is in the arrangement of the inclined standards by which the engineer is enabled to range the telescope to a vertical line. The result is obtained without any additional telescope, while the line of collimation remains on a line passing through the center of instrument; consequently all measured horizontal angles have their vertices over a center point, and no correction for offset is necessary, avoiding the inconvenience and liability of error of double telescopes.

By means of longer centers, a light counterpoise and arrangement of details the overbalance of telescope is entirely destroyed.

Transit with Duplex Telescope Bearings. — This transit answers all the purposes of the ordinary transit and in addition can be used to make highly inclined readings by setting the telescope into the bearings of an additional pair of inclined standards (Fig. 26).

Mining Transits with Lamp Targets. — Mining transits are furnished, when so ordered, to be used with mining lamp targets, detachable above the leveling screws and interchangeable with the instrument, so that in sighting forward the target is placed in position, the instrument taken from tripod and moved into forward tripod, while lamp target is substituted on the one from which the instrument (Fig. 27) is removed.

The target is the same height as the transit, measured from the parallel plate to the line of sight, and being provided with two spirit levels set at right angles and having both horizontal and vertical motion, it is quickly set to the proper angle of the line of sight by means of the sight vane. The face of the target is made of milk-white glass (on which is painted a suitable figure) and illuminated from the back by a bull's-eye lantern, which can be thrown in and out of position as desired. It is essential that lard oil be used with the lamp.

The use of three tripods with interchangeable lamp targets and transit head became very common in English collieries, and has been used to some extent in the coal mines of this country. The system has not met with favor among American engineers, however.

The Brunton Pocket Transit. — This instrument has been especially designed to meet the requirements of mining engineers,

mine managers, and geologists, its size and peculiar features adapting it to preliminary surveys both underground and on the surface, to taking topography, to geological field work, and, in short, to any purpose for which a light pocket instrument is desirable and where a moderate degree of accuracy will suffice.

This little instrument is very popular among mining engineers and deservedly so. Hardly an engineer is to be met who does not own one, and, if he is in the field, the Brunton is probably in his pocket. It weighs only 8 oz. and is $2\frac{3}{4} \times 1$ in. in dimensions.

Fig. 28 shows operator's view of instrument when using as a compass for taking horizontal angles or courses. In the mirror can be seen the reflected degree circle, needle, and level.

FIG. 28. — READING HORIZONTAL ANGLE.

FIG. 29. — READING VERTICAL ANGLE.

Fig. 29 shows the operator's view of the instrument when taking vertical angles. In this operation, the lid is raised to an angle of approximately 45° with the case; the sighting bar is straightened out until it is parallel with the face, its end being turned at right angles as shown; then the station is sighted through the hole in the end of the folding sight and the opening in the mirror, the vernier lever being turned until the bubble tube is level, which can be plainly seen in the reflected image in the mirror. When the sight has been obtained, it is better to raise the lid of the instrument and take the reading direct from the face than to attempt reading it in the mirror, where the reversal of the figures might sometimes cause an error.

Tapes

The narrow steel tape is now used for all extended measurements. For the side measurements or for radiating stope measurements, the less accurate linen or metallic tapes are sometimes allowable, but for all work requiring any degree of accuracy, the steel tape is used.

Formerly tapes ½ in., or wider, were common, but the narrow flat wire is now a favorite. For most underground work the 100-foot tape is most convenient, but the surveyor should have at hand a 200-, a 300-, and, for surface work, a 500-foot tape. Besides these, he will, of course, need a small 5- or 10-foot vest-pocket tape for measurements falling between the 5-foot marks on the long tapes and for measuring the H. I., H. P., etc.

The markings were formerly etched upon the steel ribbon.

FIG. 30. — MINER'S COMPASS.

This practice has given way to a notched brass sleeve at each 5- or 10-foot mark. The sleeve is easily found, even in the dark, the notch upon it is permanent and readily found, and the number stamped into its surface remains always legible. The ends of the sleeve are beveled so that it does not catch upon things over which it is drawn.

In the coal mines of the East a tape 310 ft. long has been a favorite. The extra 10 ft. is at the zero end, and is graduated to feet and tenths. The tape itself is graduated to 10 ft. The head chainman holds the last 10-foot mark to the forward station, and

the rear chainman then reads the additional feet and decimals from the 10-foot portion of the tape back of the zero point.

In the metal mines, the tape is stretched between the two points and the fractional part of a 5-foot division is measured with the 5-foot pocket tape. To mark the point upon the tape opposite the point to which measurement is being made, some engineers use a small clip which snaps securely upon the tape. Others simply mark the point with thumb and finger.

Where a long tape is being used, it is convenient to have a clip handle which can be fastened to the tape at any point. By using this the tape is easily pulled taut without the liability of kinking it which is present when the tape itself is taken hold of directly.

For much underground work, a reel is necessary. On the surface the reel is a nuisance, but underground it is often necessary to keep a portion of the tape wound upon it. The reel problem is a live one, and the manufacturers of surveyors' apparatus have failed to meet it as they have other problems. The reel must be strong, for it receives very rough usage, and it should be light. The crank for winding up the tape should be long to give a good leverage, and the handle upon the opposite side must be strong and so placed that the reel balances well when winding the tape in. The space for the tape must be roomy enough, so that the tape will not bind, and a spring fitted to hold it from unwinding when the reel is laid down.

Many engineers have the mine blacksmith make their reels, and others use a reel a size larger than their tape. When the tape is dirty, it will not fit into a reel of its own size. For this reason it is best to use a 500-foot reel for a 300-foot tape, etc.

The tape should, of course, be cleaned — wiped and oiled each night after using it in a wet place. As the steel tapes are easily broken when handled carelessly, it often becomes necessary to mend them in the field. A sleeve of thin copper, cut and bent to fit closely around the tape, a bottle of acid to clean the ends of the tape, a little solder and a torch, and the trick is easily done. It requires practice, however, to make a neat job of it and have the tape measure up correctly over the mended spot.

The engineer can well afford to carry a couple of patent tape splices with him. These do away with the necessity of a soldered splice till he is back in his office, or, in fact, do away with it entirely. The ends of the broken tape are inserted in a metallic sleeve

(Fig. 31) of the right size, and held by small screws turned down upon them. These do not catch upon obstructions, and will withstand the pull necessary to stretch the tape. Fig. 32 shows a punch and set used for repair of steel tapes by use of rivets.

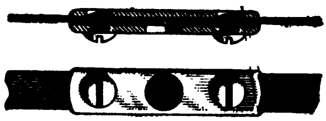


FIG. 31. — TAPE SPLICE.

No attention need be given to the corrections for temperature and sag on short tapes. The stretch on even a 300-foot tape is only nine-hundredths of a foot for 30° increase in temperature. The temperature underground seldom is many degrees different from the temperature at which the tape is standard. The sag on an unsupported 500-foot tape may be upward of five-tenths of a foot, and for that reason the long tape should be supported. The effect of sag is offset by the stretch if the correct pull is known. On short tapes, neither is appreciable.

Johnson's 'Theory and Practice of Surveying' says: 'For an accuracy of 1 in 5000, the tape may be used in all kinds of weather, held and stretched by hand, the horizontal position and amount of pull estimated by the chainman. For an accuracy of 1 in 50,000, the mean temperature of the tape should be known

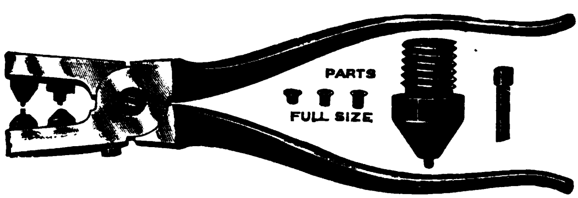


FIG. 32. — TAPE RIVETING TOOLS.

to the nearest degree Fahr., the slope should be determined by stretching over stakes or on ground whose slope is determined, the pull should be determined by spring balance.'

While the errors due to temperature, sag, and stretch are too small to be appreciable on 100-foot tapes, they must be calculated, and the corrections made, where long tapes are used on important work.

Repairing Engineers' Field Instruments [1]

The writer has frequently noticed the lack of ability on the part of many engineers to make minor repairs to their field instruments. If one is so unfortunate as to fall while carrying an instrument, it generally results in so damaging it as to render it useless to the average assistant. At such times the man with some mechanical skill and a few simple tools can make at least temporary repairs and thus save his employer considerable expense. In such an emergency an engineer who will not make an earnest attempt to repair the damage is not deserving of an honorable title. Every engineer whose work takes him some distance from a city should keep with him a few tools, such as a pair of flat pliers, a small file, large and small screw-drivers, a spool of soft brass or copper wire, a pocket knife, also an extra level vial, an ounce or two of plaster of Paris, and a bottle of liquid shellac.

The young engineer should be familiar with the details of construction of the instruments he uses, and it is to be regretted that more instruction is not given on this important subject. The catalogues of most important makers give valuable information regarding their own instruments, and also many suggestions of general application, which it would be well to study carefully.

Suppose a transit has a fall: the standards are probably bent, and a level vial broken. Many men would start for town at once under such circumstances, and possibly lose several days' time in having repairs made, but remember that the successful engineer is the one who 'does things' and never admits that he is 'stumped.' If you are of this kind, take the transit apart, lay the bent standard on a flat block of wood, and with another block of wood and a hammer or mallet proceed to straighten it. This will not be an easy task, but it can be done. The level tube should then be taken apart and cleaned out, the extra level vial inserted and blocked up with a leaf from a notebook, taking care to get the marked or convex side of the tube uppermost. If the level divisions are not cut on the glass, look for a small file scratch near one end of the vial; or if that is not apparent, put that side up which shows inside signs of grinding. Mix up a spoonful of the plaster of Paris

[1] *Engineering News*, January 25, 1906.

with water and place a portion around each end of the glass. In a few minutes this has hardened and the tube can be replaced.

Is one of the adjusting screws broken? Whittle out a new one from a piece of hard wood, fastening that end also, if necessary and possible, with a piece of copper wire.

Broken tripod legs are easily replaced with a piece of wood and some string, or wire, held in place by shellac. You may not make a neat job of your repair work, but don't mind that if you are able to complete the work assigned you without loss of time.

The writer has in mind a man of considerable skill in certain lines, who had 'accepted' an offer of a responsible position and had been placed at work. As a result of a moment's carelessness, an alidade ruler was slightly bent, and, without attempting to repair it, he rushed to the nearest telegraph office and sent a message to his chief, reading: 'I have bent my alidade ruler. What shall I do?' The answer which came back was: 'Straighten it.' This he easily did. At another time a levelman telegraphed: 'Cross wires broken; send another level,' although he knew that to do so would result in a delay of several days; the answer he received was, 'If you can't insert new cross wires, disband your party,' and with the possibility of discharge as a stimulant he found that repairs were easily made. Still another levelman, who could not catch his chief by telegraph, stopped the work of his party and sent his Y-level nearly 1000 miles to an instrument maker in order that the eyepiece might be centered on the cross-wires. He could have remedied that trouble in five minutes by the proper manipulation of a screw-driver. No error would have been introduced into his work, even if the cross wires were not in the center of the field of view, so long as the usual level adjustment had been made. This man had not learned to distinguish between a blemish and a fatal defect.

During the past year in certain instrumental work under the writer's charge, an expense of over fifty dollars was incurred in having new cross wires inserted by an instrument maker, not including the loss of time by the various parties.

Broken cross wires are of frequent occurrence, and are easy to replace if one knows how; consequently the writer is now requiring his assistants to learn how; and in order to aid them he has prepared a description of the process, which, as it may be of use to others, is here given in full:

A small bottle of shellac dissolved in alcohol (preferably a thin solution, as that will dry quicker) and a cocoon of spider web are needed. The only tools required are a pair of dividers, or a 6-inch piece of soft iron, or copper, wire bent to a U, and if neither is available, a forked stick will answer. The dividers, wire or forked stick, should have a small piece of beeswax pressed around each end to hold the web. A couple of small pointed sticks the size of matches are useful.

The best cocoons for ordinary use are yellowish-brown, about $\frac{3}{4}$ in. long; they may usually be found in dead or hollow trees, or under the bark of old stumps. Good ones may often be found under rocks, or in old barns or greenhouses. Occasionally single webs, which may be used in an emergency, may be taken from grass or bushes or limbs of trees; these are generally rough and dirty, but some of their defects may be removed by gently rubbing them with a small stick. If a very fine web is needed, it may be secured from a small white cocoon. A good cocoon will furnish enough webs to last for years, and each chief of party should have one packed with the shellac in his instrument box. The best web obtainable can be secured by making a spider spin one as he falls from the end of a stick. A small spider will probably spin a fine web, and a large spider a coarser web; such webs are always smooth and free from dust. If the spider is made to jump from the end of the dividers, or forked stick, the web can be wrapped around the ends and so be in position for immediate use.

Take the instrument which needs the new cross wires to a place sheltered from wind and dust. Unscrew and remove the eyepiece slide without disturbing the object glass. Take out two opposite capstan-headed screws of the four which hold the cross-wire ring in its cell, and loosen the other two. Using the latter as handles, revolve the ring 90° and insert one of the pointed sticks through the end of the telescope tube into a screw hole; and, while using it as a handle, remove the other screws and take out the ring. Clean the lines of the reticule ring from all old shellac or dirt and lay it on a board or table with the marked side up. Draw some of the web from the cocoon, either with the fingers, or with one of the moistened, pointed sticks. Keep pulling and working the tangled mass until an inch or two of single web is drawn out. Attach the ends of the web to the dividers, or wire, by winding them around the wax and pressing them in with

the fingers; or wind the web around the forked stick, fastening it with shellac. Examine the web for defects by means of a pocket magnifier, or the eyepiece from the telescope. If the web is satisfactory in size and quality, moisten it by dipping it in water for a few seconds or by breathing gently on it a few times. As the wet web lengthens, take up the slack by opening the dividers, or by bending the wire or stick, but do not attempt to stretch the web more than about $\frac{1}{16}$ in., from its original dry length. Place the web (still on its holder) carefully over the reticule, allowing the holder to rest on the table, thus stretching the web slightly, and move it about until it falls exactly in the center of two opposite lines, using a magnifier to insure accuracy. Put a small portion of the liquid shellac over each side of the web, about $\frac{1}{16}$ in. from the central opening of the reticule, and leave undisturbed for 3 or 4 minutes, or until the shellac hardens. While the shellac on one web is drying, another can be prepared. After all are set, replace the reticule in the telescope by reversing the method used in removing it. When in place the cross wires should be on the side of the rig toward the eyepiece.

Instruments such as the prism level, dumpy levels, and transits, not provided with wyes or similar devices for adjusting the cross wires, may be put in close adjustment by means of improvised wooden, or metal, rings in the following manner:

For the prism level, the body of which has a close finish, remove the object-glass cap and run the eyepiece slide part way out as though focusing for a near-by object. Provide a Y of wood, or metal, large enough to fit over the object-glass end of the telescope where the cap usually fits. Take a second Y of a size suitable to enclose the eyepiece slide near the main telescope tube. Fasten these Y's securely in an upright position and rest the telescope in them, sight a distant point which the cross wires cut, revolve the telescope in the wyes and adjust the cross wires in the usual way. A final adjustment must be made for such instruments as this by the usual methods.

But prevention is always better than cure, and a great many instrument troubles may be prevented by care in handling the instruments, and by the frequent application of a little oil (a very little will answer) to spindles, leveling screws, tangent screws, and telescope slides. An occasional cleaning with an oily rag will work wonders. Never overstrain a screw; make it snug and no more.

The workman who takes good care of his tools, who learns to do good work with the means available, is not the man who fills his report with excuses. He knows it is results that are wanted, not excuses.

The atmosphere of a mine is generally warm and moist. It is, then, quite necessary that all the surveyor's instruments be kept in a warm room. Otherwise they will condense the moisture of the atmosphere when taken underground, and the glass become fogged and the metal parts rusted.

Bibliography. — Surveyors' Instruments, *Eng. and Min. Jour.*, vol. ix, p. 8, 1906; Transit Instruments, *ibid.*, August 25, 1904; Tapes, *ibid.*, vol. iii, p. 95, 175; Hanging Compass, *ibid.*, vol. vii, p. 1, 1891; Repair of Instruments, *Eng. News*, vol. i, p. 25, 1906; Imperfections and Improvements of Surveyors' Instruments, *Trans. A. I. M. E.*, vol. vii, p. 308; Evolution of Instruments, *ibid.*, vol. xxviii; Thornton's Miner's Dial, *ibid.*, xxxviii; Plummet Lamps, *ibid.*, vol. viii, p. 39; Glass Stadia Rod, *Jour. Franklin Inst.*, vol. iv, 1868; Dialing Trouble and Treatment, *Col. Guard*, vol. i, p. 21, 1898; Adjustment of Surveying Instruments, *Proc. Inst. Mine Surv.* (Transvaal), vol. ii; Photographic Survey Instruments, *Trans. Soc. of Engineering*, p. 171, 1899; Dip Needle, *Lake Superior M. Inst.*, August, 1904; Surveyors' Instruments, *Mining Reporter*, vol. ix, p. 29, 1904; Repairing Engineers' Instruments, *Mining Reporter*, vol. ii, p. 8, 1906; Compass on Tripod, *M. and Sci. P.*, vol. x, p. 15, 1904.

II

MERIDIAN

The lines of the survey of a property may be referred to the lines of other surveys by various methods. One very often used is that of connecting by traverse with the survey lines of the adjoining properties. The Government requires that this method be used in connecting a claim survey with the public-land survey. Where the lines of the adjoining property may be assumed as correctly surveyed one can take the meridian directly from them.

To observe the meridian instrumentally one has choice of three methods, namely, observation of the transit or elongation of some star, observation of the sun by means of a solar compass, or direct sun observation with the ordinary transit.

To use the first method one must have a star almanac; to use the second one must have a solar attachment.

Polaris Observations

It is sometimes convenient to be able to take the meridian from Polaris at a time when one is without a star almanac to learn when Polaris is at elongation or culmination.

Observations are usually made upon Polaris when it is at elongation, if possible at both eastern and western elongation, and the difference of the two observations taken as true north. If one will but remember that the Great Dipper and Polaris are on opposite sides of the true north, one can instantly tell by a glance at the heavens whether Polaris is near either elongation or culmination.

Now the third star in the handle of the dipper, counting from the outer end, whose name is Alioth, is almost directly opposite Polaris. It does, however, lie a little more than 180° ahead of Polaris. It crosses the meridian below the true north just twenty-four and a half minutes of time before Polaris crosses it above. Also, of course, it is at one elongation just twenty-four and a half

minutes before Polaris is at the other. If, then, one sees both Alioth and Polaris under the vertical wire of his telescope, he knows that in twenty-four and a half minutes Polaris will be in the true meridian. The same applies to the horizontal wire when Polaris is at elongation (Fig. 33).

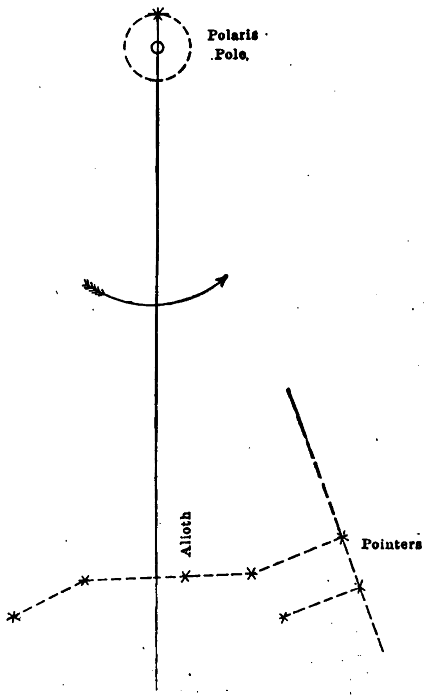


FIG. 33. — POLARIS OBSERVATION.

Explanation of the Solar Attachment[1]

'In the engraving (Fig. 34) we have a graphic illustration of the solar apparatus, the circles shown being intended to represent those supposed to be drawn upon the concave surface of the heavens.

'When the telescope is set horizontal by its spirit level, the hour circle will be in the plane of the horizon, the polar axis will point to the zenith, and the zeros of the vertical arc and its vernier

[1] From 'Gurley's Manual.'

will coincide. Now, if we incline the telescope, directed north as shown in the cut, the polar axis will descend from the direction of the zenith. The angle through which it moves being laid off

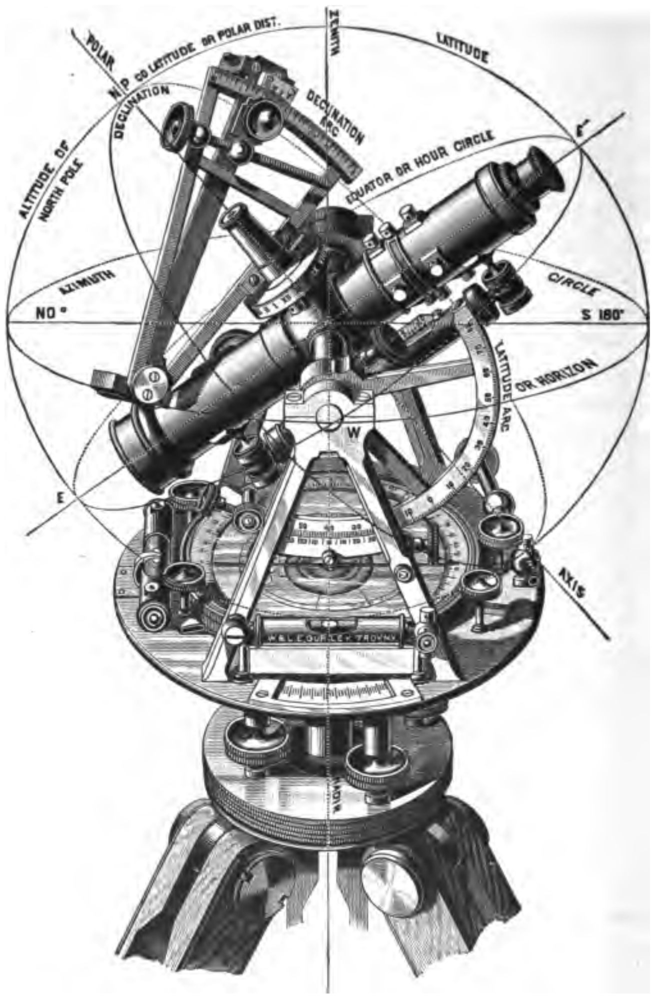


FIG. 34. — SOLAR APPARATUS.

on the vertical arc, will be the colatitude of the place where the instrument is supposed to be used, the latitude itself being found by subtracting this number from 90°.

'When the sun passes above or below the equator, its declination, or angular distance from it, as given in the "Ephemeris," can be set off upon the declination arc, and its image brought into position as before.

'In order to do this, however, it is necessary not only that the latitude and declination be correctly set off upon their respective arcs, but also that the instrument be moved in azimuth until the polar axis points to the pole of the heavens, or, in other words, is placed in the plane of the meridian; and thus the position of the sun's image will indicate not only the latitude of the place, the declination of the sun for the given hour and the apparent time, but it will also determine the meridian, or true north and south line passing through the place where the observation is made.

'The interval between two equatorial lines, *c c*, as well as between the hour lines, *b b*, is just sufficient to include the circular image of the sun, as formed by the solar lens on the opposite end of the revolving arm.

'*Allowance for Declination.* — Let us now suppose the observation made when the sun has passed the equinoctial point, and when its position is affected by declination.

'By referring to the "Ephemeris," and setting off on the arc the declination for the given day and hour, we are still able to determine its position with the same certainty as if it remained on the equator.

'When the sun's declination is south, that is, from the 22d of September to the 20th of March in each year, the arc is turned downward, or *toward* the plates of the transit, while during the remainder of the year the arc is turned *from* the plates.

'When the solar attachment is accurately adjusted and the transit plates made perfectly horizontal, the latitude of the place and the declination of the sun for the given day and hour being also set off on their respective arcs, and the instrument set approximately north by the magnetic needle, *the image of the sun cannot be brought between the equatorial lines until the polar axis is placed in the plane of the meridian of the place, or in a position parallel with the axis of the earth.* The slightest deviation from this position will cause the image to pass above or below the lines, and thus discover the error.

'From the position of the sun in the solar system, we thus obtain

a direction absolutely unchangeable, from which to run lines and measure horizontal angles.

'This simple principle is not only the basis of the construction of solar instruments, but it is the only cause of their superiority

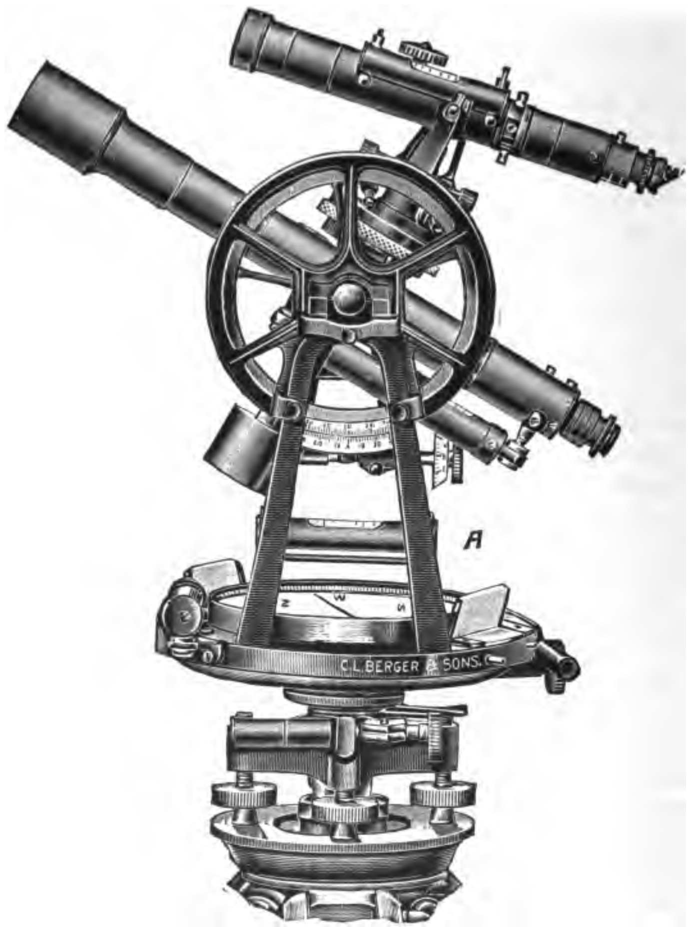


FIG. 35. — SOLAR TELESCOPE ATTACHMENT.

over instruments having the ordinary magnetic needle. For in an instrument having a magnetic needle, the accuracy of the horizontal angles indicated, and therefore of all the observations made depends upon the delicacy of the needle and the constancy with which it assumes a certain direction, called the magnetic meridian.'

Direct Solar Observation [1]

'Of the applications of plane surveying to the survey of mineral lands, no one is more representative, or has been more greatly perfected in the West, than the use of the sun to determine the bearing of a given line. For many years bearings were determined by the use of various solar attachments, but of late years the method known as the direct observation seems to have almost entirely taken their place. While with great care any one of the several solar attachments on the market will give fair or even good results, they are all relatively expensive, fragile, and, with one exception, easily thrown out of adjustment. With the method known as "the direct observation" no attachment is needed to the ordinary transit provided with a vertical arc or circle, preferably the latter, and no adjustment has to be considered other than those necessary to use in every transit in mineral-land surveying.

FIG. 36. — SOLAR SCREEN.

'As the exact determination of the bearings of lines is probably more important in mineral-land surveying than in any other branch of engineering, perhaps, disregarding of course geodetic work, it will be taken up in detail.

'To determine the bearing of a line by direct observation, the transit is set up as solidly as possible and carefully leveled. The line whose bearing is to be determined may be considered 0° and the upper plate set at 0°; or, if the bearing is approximately known, the upper plate may be set at the assumed bearing to be afterwards corrected. If more convenient, the assumed bearing of a line to

[1] This article is reprinted, by permission, from 'Mineral Land Surveying,' by James Underhill, Ph.D., published by the Mining Reporter Publishing Company.

some prominent object may be taken, and the first course required on the survey deflected from this line. The upper plate is then loosened and the telescope pointed at the sun. The sun may be observed in various ways; for example, through a colored glass placed over the eyepiece to which may be added a prism when the

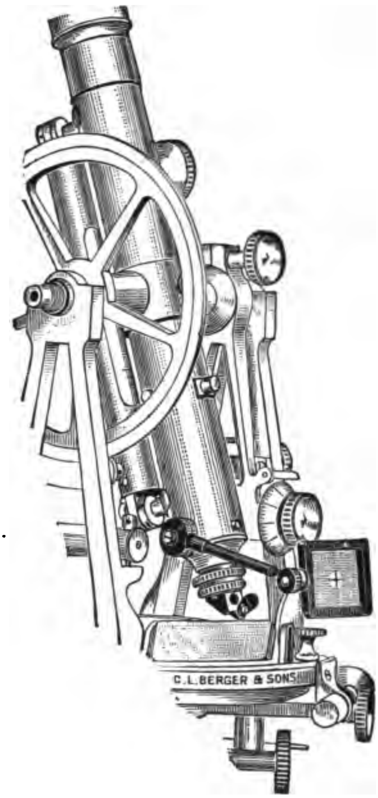


FIG. 37.— PRISMATIC EYEPIECE AND SCREEN.

sun is very high. This colored glass may be conveniently placed in the sliding cover of the eyepieoe and is thus always ready for use. As this method involves the attachment of the colored glass, and also when the sun is high some personal discomfort as regards the position of the head, a card, sheet of paper, or better the brown back of a notebook, which latter does away with the glare on the white surface, may be used. On this surface, preferably held by

the assistant, the cross wires are first focused, and finally the sun is brought into the proper position by the aid of the tangent screws.

A Davis screen is a piece of apparatus attached to the telescope to answer the same purpose as the card mentioned above, and its use leaves both hands free to manipulate the instrument. Otherwise it is of no great advantage (Figs. 36 and 37).

In regard to placing the sun with reference to cross wires, there are many opinions. In most treatises we are instructed not to

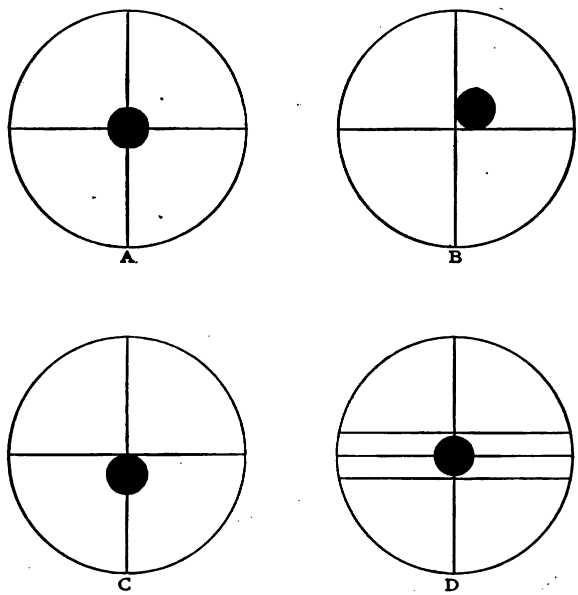


FIG. 38. — SUN'S IMAGE ON CROSS HAIRS.

bisect the sun as in Fig. 38A, but to place it in one quadrant, as in Fig. 38B, as it can thus be observed more accurately. While this is perfectly true, especially with inverting instruments, a correction for semidiameter of the sun must be made, and the operation is liable to be somewhat confusing to the beginner. The student is therefore advised at first to divide the sun into quadrants by the two cross hairs (Fig. 38A), leaving the method of placing the cross hairs tangent until proficiency is secured. As an error of one minute in placing the vertical cross wire causes an error of one minute in the resulting azimuth, while an error of one minute in

placing the horizontal wire causes an error of several minutes in the result, it might be well to place the sun as in Fig. 38c. The reason for this will readily be seen on examining the examples which follow. The sun in very accurate work is sometimes placed in a rectangle or other arrangement of cross wires, but in ordinary work these are unnecessary refinements.

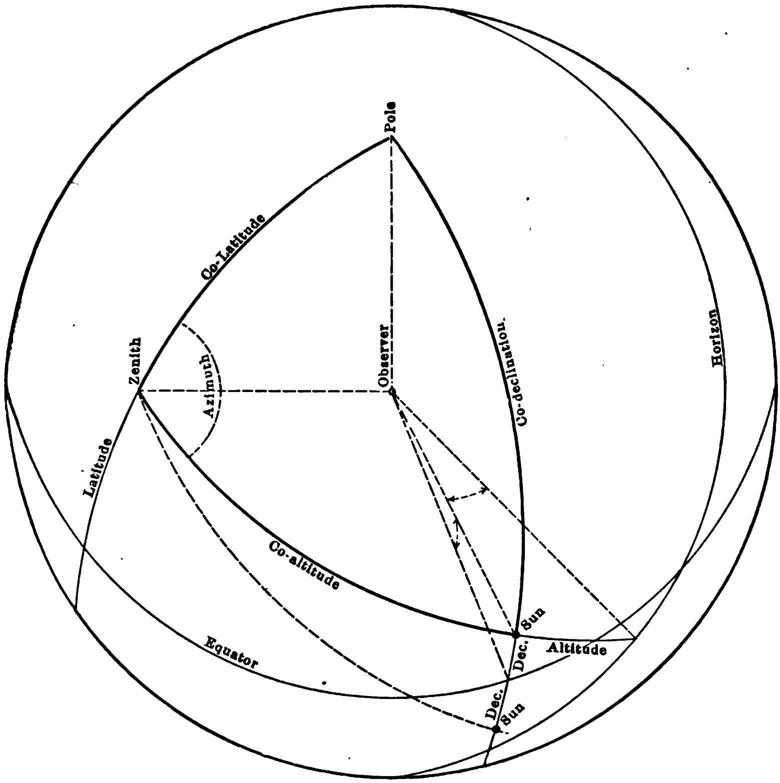


FIG. 39. — STAR SPHERE.

'Another very exact method of placing the sun in the direct observation is to place it tangent to the cross wires first in the northeast corner with the telescope normal, and then in the southwest corner with the telescope inverted. These are the best positions in the morning. In the afternoon the other two quadrants had best be used in order that the sun may be moving in the same direction with reference to the cross wires. The average of

the two vertical and two horizontal angles is used in each case in the subsequent calculations and in this way all consideration of the semidiameter of the sun is avoided. At least two sets of such observations must be made, otherwise there is no check.

'In an instrument provided with stadia wires care must be taken not to confuse these with the horizontal cross wire. It is also well not to assume that the stadia wires are each equally distant from the horizontal cross wire.

'If the stadia wires are correctly placed they should be 0° 34′ 22″ apart, and each 0° 17′ 11″ from the center horizontal wire. As the sun's semidiameter varies round 0° 16′ the stadia wires may be used with advantage to place the sun with a very slight probable error (Fig. 38D).

'We will assume that the sun has been bisected. The vertical and horizontal circles are then read and noted, and an observation made with the telescope inverted, assuming that the first observation was made with the telescope normal. By averaging the two results all errors of adjustment or in leveling the instrument are obviated. As a check a number of observations may be made on the sun, and the writer finds that two each, with normal and inverted telescope, are sufficient. The observations should not be made within two hours on each side of noon, nor when the sun is too near the horizon, as the correction for refraction is then too great.

'The direct solar observation depends on the solution of a spherical triangle (see Fig. 39[1]) whose sides are all known, and whose angle between two planes is desired. These planes, as can be seen from the figure, are (one) observer, zenith, pole; and (the other) observer, zenith, sun. In our work we have first the latitude, distance from pole to horizon or from zenith to equator; and therefore the colatitude (90° latitude) for one side, or in other words we have from pole to zenith; we have the declination, distance of the sun above or below the equator and therefore the codeclination (90° declination), that is from pole to sun, and we finally get the altitude and thence the coaltitude (90° the altitude), by the solar observation with the transit as described above. In Fig. 39 the sun is shown by solid lines north of the equator and

[1] Redrawn from the *Bulletin*, Colorado School of Mines, January, 1901, 'Determination of the Meridian by the Direct Solar Observation,' Edward P. Arthur, Jr., E.M.

by dotted lines south of the equator, this also showing its position before noon. This triangle may be solved by any one of the various formulas found in every treatise on spherical trigonometry.

'The best formula, however, for the direct observation is that derived by John G. McElroy, of Breckenridge, Colorado, and given in the *Michigan Engineers' Annual* for 1889, p. 62, as follows:

$$\text{'}\cos Z = \pm\frac{\sin d}{\cos l \cos a} \mp \tan l \tan a,$$

which is simply a modification of one of the fundamental equations of spherical trigonometry.

'Before illustrating the utility of the formula and the facility with which it may be logarithmically reduced, it will be proper, for the sake of completion, to give the argument on which it rests. To this end let $P\ Z\ S$, Fig. 40, be a spherical triangle, and k an arc of the great circle drawn from Z perpendicular to $P\ S$, or to $P\ S$ produced.

Then from the triangle $P\ Z\ D$,

$$\cos s = \cos k \cos (z - x): \qquad (1)$$

and from the triangle $S\ Z\ D$,

$$\cos p = \cos k \cos x \qquad (2)$$

Eliminating $\cos k$, we find

$$\frac{\cos s}{\cos p} = \frac{\cos (z-x)}{\cos x} = \sin z \tan x \qquad (3)$$

But from $S\ Z\ D$ $\cos S = \tan x \cos p$;

$$\text{whence, } \tan x = \frac{\sin p}{\cos p} \cos S \qquad (4)$$

Placing this in (3) there results

$$\frac{\cos s}{\cos p} = \cos z + \frac{\sin p \sin z}{\cos p} \cos S;$$

$$\text{or, } \cos s = \cos p \cos z + \sin p \sin z \cos S \qquad (5)$$

'This is the above-mentioned fundamental equation. It asserts that the cosine of either side of a spherical triangle equals the product of the cosines of the other sides, plus the product of the sines of those sides into the cosine of their included angle. To apply it to the derivation of our solar formula let us consider Fig. 41, which represents the four astronomical triangles PZS, PZS', $P'Z'S$, and $P'Z'S'$, projected on the plane of the meridian

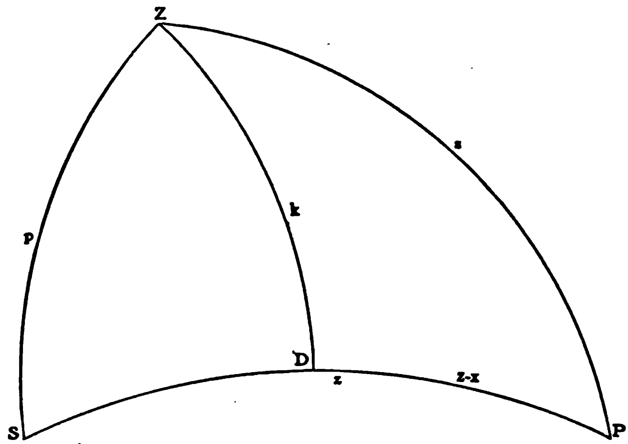


FIG. 40. — SPHERICAL TRIANGLE.

PNHZ. In A.M. observations, the azimuth angles at Z or Z' will be estimated from the north to the right; in P.M. observations, from the north to the left.

'We adopt the following notation:

PP' = axis of the celestial sphere.
P = the celestial north pole.
P' = the celestial south pole.
EQ = the celestial equator.
HO = the celestial horizon of which the poles are Z and N.
Z and N = zenith and nadir of an observer in north latitude.
Z' and N' = zenith and nadir of an observer in south latitude.[1]
$EZ = 1$ = observer's latitude when at Z.
$EZ' = 1$ = observer's latitude when at Z'.
S = the sun when north of the equator.
S' = the sun when south of the equator.
$VS = d$ = the sun's declination when north.
$VS' = d$ = the sun's declination when south.
PS = the sun's north polar distance when north.
PS' = the sun's north polar distance when south.
$mS = a$ = the sun's altitude when north.
$m'S' = a$ = the sun's altitude when south.
pp' = the sun's daily path when north.
$p^1 p^2$ = the sun's daily path when south.

[1] The horizon of which Z' and N' are the poles is not shown in the figure; it would be projected as a diameter perpendicular to $Z' N'$.

'It will be sufficient to consider the particular case of an observer in north latitude, and the sun in north declination (whence *d* and 1 are positive; *a* is always positive) and then make our results general by properly observing the signs of *d* and 1.

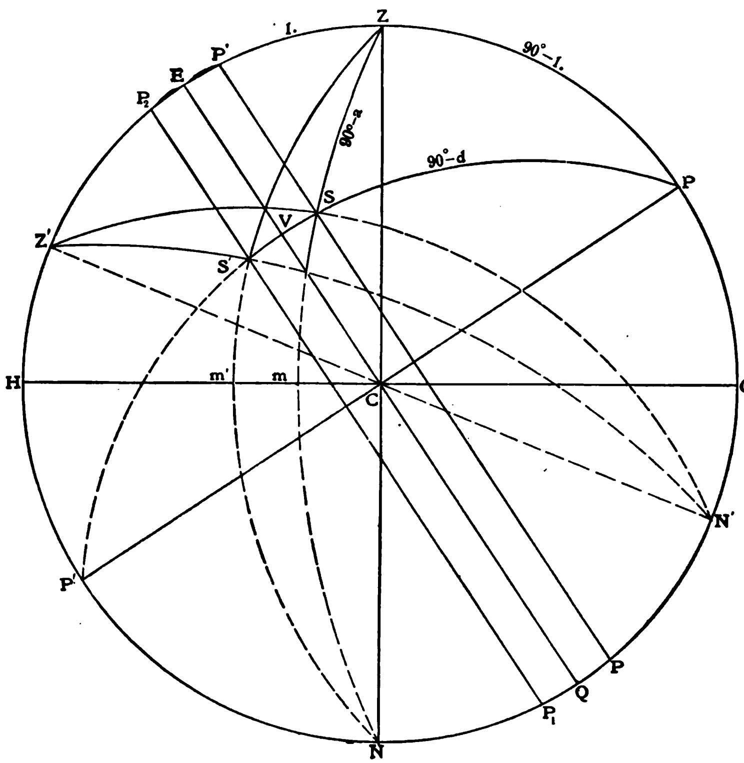


FIG. 41. — PROJECTION OF STAR SPHERE.

'The case assumed is illustrated by the triangle *PZS* (Fig. 41), in which

$$PS = 90° - VS = 90° - d,$$
$$PZ = 90° - EZ = 90° - 1,$$
$$SZ = 90° - mS = 90° - a,$$

and the sun's azimuth angle *PZS* is required. It is found thus:

'By applying the principle of which equation (5) is the enunciation to the angle *PZS*, we have:

$\cos PS = \cos PZ. \ \cos SZ + \sin PZ. \ \sin SZ. \ \cos Z$; or,
$\cos(90° - d) = \cos(90° - 1) \cos(90° - a) + \sin(90° - 1) \sin(90° - a) \cos Z$,

$$\text{whence, } \sin d = \sin 1 \sin a + \cos 1 \cos a \cos Z;$$

$$\text{from this, } \cos Z = \frac{\sin d}{\cos 1 \cos a} - \tan 1 \tan a \qquad (6)$$

'In (6) $\cos 1$, $\cos a$, and $\tan a$ are always positive, but $\sin d$ and $\tan 1$ will respectively have the signs of d and 1; hence to prevent mistakes it is advisable to write the expression in the form:

$$\cos Z = \pm \frac{\sin d}{\cos 1 \cos a} \mp \tan 1 \tan a \qquad (7)$$

which is the desired solar formula.

'With respect to the signs of the formula the surveyor has simply to remember that the first term of the second member is

+ for north declinations,
− for south declinations,

and that the second term is

− for north latitudes,
+ for south latitudes.

For north latitudes the formula always gives negative values for cos Z when the declination is south, and also for such north declinations and values of a as render $\sin d$ less than $\sin 1 \sin a$; but when $\cos Z$ is negative Z is greater than 90°, and hence the positive value of the cosine, as taken from the table of Naturals, is the cosine of $(180° - Z)$, (i.e., of EZS, the azimuth from the south) for $-\cos Z = \cos(180° - Z)$.'''

'As an example we will take the following series of direct observations on the sun, the first two with telescope normal, the last two with telescope inverted:

Angle to Right from Line to be Determined	Altitude of Sun
233° 16′ (See Fig. 42)	52° 51′
233 33	53 03
234 01	53 18
234 17	53 29

July 22, 1905, 10 A.M., latitude 39° 47′ north. Longitude 7h. W. of Greenwich.

Declination Greenwich apparent noon......	20° 22′ 18.1″
Less 5 hours west......................	2′ 27.0″
	20° 19′ 51.1″

Difference for 1 hour = 29″.45

$$\begin{array}{r} 5 \\ 60\overline{)\,147''.25} \end{array}$$

Difference for 5 hours = 2′27″

Call 20° 19′ 51″ = 20° 20′

$$\text{Cos azimuth} = +\frac{\sin 20^\circ\ 20'}{\cos 39^\circ\ 47' \cos 52^\circ\ 50'^{1}, \text{ etc.}} \qquad \begin{array}{c} -\tan 39^\circ\ 47' \\ (\tan 52^\circ\ 50'^{1}, \text{etc.}) \end{array}$$

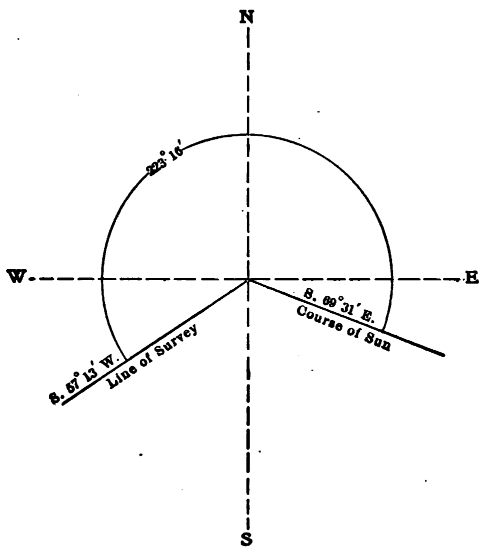


FIG. 42.—OBSERVATION FOR MERIDIAN.

$$\begin{aligned} \log \sin 20^\circ\ 20' &= 9.540931 \\ \log \cos 39^\circ\ 47' &= \underline{9.885627} \\ & \ 9.655304 \end{aligned}$$

$$\begin{aligned} & \ 9.655304 \\ \log \cos 52^\circ\ 50' &= \underline{9.781134} \\ \log 0.7485 &= 9.874170 \end{aligned}$$

[1] Corrected for refraction—always diminished.

Another computation from this formula is given by McElroy on p. 68, 1899 *Mich. Eng. Annual.*

log tan 39° 47′ = 9.920476
log tan 52° 50′ = 10.120259

log 1.0984 = 0.040735
0.7485

0.3499 = nat cos 69° 31′ (course of sun)
233° 16′

302° 47′

9.655304
log cos 53° 2′ = 9.779128

log 0.7519 = 9.876178
log tan 39° 47′ = 9.920476
log tan 53° 2′ = 10.123411

log 1.1066 = 0.043887
0.7519

0.3547 = nat cos 69° 14′ (course of sun)
233° 33′

302° 47′

360° 00′
302° 47′

S. 57° 13′ W. (see Fig. 42)

9.655304
log cos 53° 17′ = 9.776598

log 0.7564 = 9.878706

log tan 39° 47′ = 9.920476
log tan 53° 17′ = 10.127360

log 1.1163 = 0.047836
0.7564

0.3599 = nat cos 68° 54′
234° 01′

302° 55′

9.655304
log cos 53° 28′ = 9.774729

log 0.7596 = 9.880575

$$\begin{array}{lcl}
\log \tan 39^\circ\ 47' & = & 9.920476 \\
\log \tan 53^\circ\ 28' & = & \underline{10.130263} \\
\log 1.1239 & = & 0.050739
\end{array}$$

$$\begin{array}{l}
0.7596 \\
\hline
0.3643 = \text{nat cos } 68^\circ\ 38' \\
\qquad\qquad\qquad\quad \underline{234^\circ\ 17'} \\
\qquad\qquad\qquad\quad 302^\circ\ 55'
\end{array}$$

$$\begin{array}{rl}
13' & \\
13' & \\
05' & \qquad 360^\circ\ 00' \\
05' & \qquad \underline{302^\circ\ 55'} \\
4)\underline{36'} & \quad \text{S. } 57^\circ\ 5'\ \text{W.} \\
9' &
\end{array}$$

Average course of line S. 57° 9′ W.

'It will be seen that the cosine and tangent of the latitude and altitude, respectively, are found on the same line in the tables, and are set down at the same time for calculation.

'The sun's semidiameter varies from about 16′ 15″ on January 1st to 15′ 45″ on July 2d, and is found in the "Ephemeris." The average, 16′ nearly, will do for ordinary work.

'The refraction, always subtracted from the apparent altitude, is 57″ × tan zenith distance of sun, or by table.

MEAN REFRACTION (TO BE SUBTRACTED FROM OBSERVED ALTITUDE) BAROMETER 30 INCHES; THERMOMETER 50° F.

Altitude	Refraction	Altitude	Refraction
10°	5′ 19″	20°	2′ 39″
11	4 51	25	2 04
12	4 27	30	1 41
13	4 07	35	1 23
14	3 49	40	1 09
15	3 34	45	58
16	3 20	50	49
17	3 08	60	34
18	2 57	70	21
19	2 48	80	10

'The declination is taken from any ephemeris such as is published by many instrument makers. At Denver we are seven

hours later in apparent time than Greenwich, one hour for each 15° of longitude, and this difference in time multiplied by the hourly difference given in the 'Ephemeris' is added or subtracted as the declination is increasing or decreasing, to or from the declination given for Greenwich noon.

'*Latitude.* — The latitude is taken from any good map, such as those of the 'United States Geological Survey,' and carried from the initial point when necessary. One minute of latitude equals 6070 ft., or 1 mile equals 52 seconds of latitude. A surveyor doing considerable work in one district will prepare a table showing cosines and tangents for latitudes likely to be of use, and thus avoid looking them up in a large table every time an observation is figured.

'When the latitude is known approximately observations may be taken at equal intervals before and after apparent noon, and various figures for latitude tried till one is found which gives the same azimuth in the morning as in the afternoon. When the latitude is absolutely unknown, it may be found as follows: Set up the instrument in plenty of time before apparent noon. Bisect the sun with vertical cross wire, and either bisect it with horizontal cross wire or place tangent. Follow the sun till it ceases to rise. Care must be taken in the observation to allow plenty of space through which the tangent screws may be moved, otherwise they are liable to give out at a critical moment. As the instrument cannot be reversed as in the case of the direct sight, it is well to level the telescope immediately after the observation and note the index error, adding or subtracting it for the angle observed. In instruments with movable arc, the arc had best be set at zero immediately after getting the sun. The telescope is then leveled and the angle read, thus avoiding errors incidental to settling of the instrument during a long observation.

'When the observer is north of the equator the latitude then equals the zenith distance plus the declination for apparent noon. Lat. = (90° − altitude [1]) + declination, when the sun is north of the equator, and Lat. = (90° − altitude [1]) − declination, when the sun is south of the equator.

'When the observer is south of the equator the above is reversed.

[1] Corrected for refraction.

'In Fig. 43, which represents a section of the celestial sphere on the meridian, we have *ZN* zenith to nadir line, *PP'* line joining the poles, *QQ* the equator, and *HH'* the horizon, while *S* and *S'*

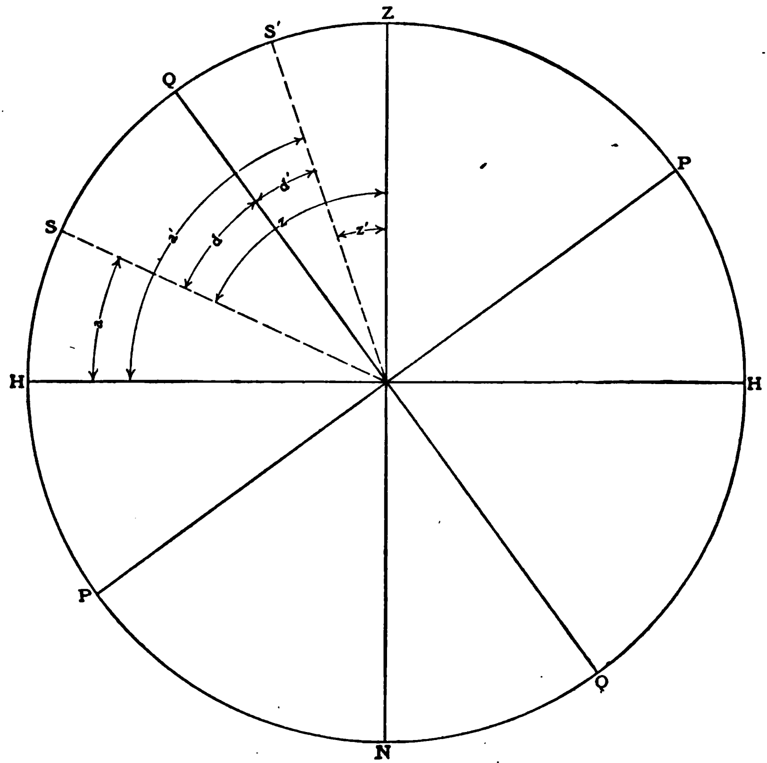


FIG. 43.—SECTION OF STAR SPHERE.

shows the position of the sun, *A* and *A'* the zenith distance, *a* and *a'* the altitude and *d* and *d'* the declinations, respectively, when the sun is south or north of the equator, and the observer in north latitude. Example:

October 20, 1905; 12 M.; Longitude 105° 30' + W.

Altitude sun's upper limb	$=40° \ 15'$
Less refraction	$= \ 0° \ \ 1'$
Less semidiameter	$= \ 0° \ 16'$
Altitude sun's center	$=39° \ 58'$

Declination Greenwich A. T.	$=10°\ 11'\ 50''$
Difference 1 hr. = 54.01 difference 7 hrs. =	$6'\ 30''$
Declination Longitude 105° 30′ + W.	$=10°\ 18'\ 20''$
Altitude sun's center	$=39°\ 58'$
	$50°\ 16'\ 20''$
	$90°\ 00'\ 00''$
	$50°\ 16'\ 20''$
Latitude place of observation	$=39°\ 43'\ 40''$

'By inspection of the following table, errors resulting from the use of erroneous data for declination or latitude may be found.

Errors in Azimuth for 1 Minute Error in Declination or Latitude

No. of Hours from Noon	For 1 Minute Error in Declination			For 1 Minute Error in Latitude		
	Lat. 30°	Lat. 40°	Lat. 50°	Lat. 30°	Lat. 40°	Lat. 50°
H. M.	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*
0 30........	8.85	10.00	12.90	8.77	9.92	11.80
1 00........	4.46	5.05	6.01	4.33	4.87	5.80
2 00........	2.31	2.61	3.11	2.00	2.26	2.70
3 00........	1.63	1.85	2.20	1.15	1.30	1.56
4 00........	1.34	1.51	1.80	0.67	0.75	0.90
5 00........	1.20	1.35	1.61	0.31	0.35	0.37
6 00........	1.15	1.30	1.56	0.00	0.00	0.00

'By the use of the above table the amount of the azimuth error, resulting from the use of erroneous declination or latitude at the different hours of the day, may be determined.

'If the South Polar distance used be too great, the observed meridian falls to the right of the true south point in the forenoon, and to the left in the afternoon, and *vice versa* if too small.

'If the latitude used be too great, the observed meridian falls to the left of the true south point in the forenoon, and to the right in the afternoon, and *vice versa* if too small.

'Another formula for direct sight, though not so convenient

when many observations are to be worked out, but still useful as a check, is as follows:

$$\text{Sin } \tfrac{1}{2} A = \sqrt{\frac{\sin (S-L) \sin (S-h)}{\cos L \cos h}}$$

$$S = \frac{L+h+P}{2}$$

A = Azimuth of the sun.
L = Latitude of the place.
h = Altitude of the sun less refraction.
p = Sun's polar distance = $90° +$ sun's declination when it is south and $90° -$ the sun's declination when it is north.

'Example:

$$\begin{aligned} L &= \ \ 40° \ 30' \\ h &= \ \ 23° \ 05' \\ p &= 107° \ 03' \\ \hline & \ \ 170° \ 38' \div 2 = 85° \ 19' = S. \end{aligned}$$

$S - L = 44° \ 49'$ $\quad S - h = 62° \ 14'$

log sin	$44° \ 49' =$	9.848091
log sin	$62° \ 14' =$	9.946871
log 10 − cos	$40° \ 30' =$	0.118954
log 10 − cos	$23° \ 05' =$	0.036243
	2)	19.950159
log sin $\frac{1}{2} A$	=	9.975079
$\frac{1}{2} A$	=	70° 46′
A	=	141° 32′

$180° - 141° \ 32' = S \ 38° \ 28' \ E$, course of observed sun.

'As A is here doubled, all errors to this point are therefore doubled.'

A Graphic Solution of the Direct Solar Observation [1]

'In the description which follows a graphical method is proposed for solving the spherical triangle in which the three sides are given and the azimuth angle is required. After directly ob-

[1] By James Underhill, Ph.D.

serving the altitude of the sun with the transit, the azimuth is usually obtained at the present time by the following formula:

$$\cos Z = \pm \frac{\sin d}{\cos a \cos l} \mp \tan a \tan l,$$

in which

Z = azimuth required.
d = declination.
l = latitude.
a = altitude of sun corrected for refraction.

'The first term of the second member is

+ for north declinations,
− for south declinations,

and the second term is

− for north latitudes,
+ for south latitudes.

'As this formula can be transformed into

$$\cos Z = \pm \sin d \sec a \sec l \mp \tan a \tan l,$$

it will be seen at once that any method of solution providing for two multiplications in the first term of the second member and one multiplication in the second term, will answer. The graphical method here proposed is probably as simple as any.

'In order that the use of the logarithmic cross-section paper may be easily understood by those to whom it is unfamiliar, Fig. 44, has been added. Here the coördinates have been arranged logarithmically. If we take 3 on one ordinate and 2 on the other, we find that they intersect on the inclined line 6. It makes no difference on which ordinate we take the 3 or 2. This holds true, of course, for any multiplication. For continued multiplication, let us take $3 \times 5 \times 2$. At the intersection of 3 and 5 find 15, follow this inclined line till it reaches the upper abscissa, follow down the ordinate till it intersects the abscissa for 2, and on its inclined line find 3, which, by proper pointing off, will read 30, as with a slide rule. The accuracy of this method is limited only by the scale and size of the paper used. The efficiency is increased for most problems by repeating the logarithmic series, as is done in the upper scale on the ordinary slide rule. Having

used the ordinary logarithmic cross-section paper, we are now ready for logarithmic paper, divided for the trigonometric functions.

'*Method of Using the Plate.* — As an example of the use of this method, let us take the following problem, the first given on p. 78: $d=20°\ 20'$; $l=39°\ 47'$; $a=52°\ 50'$. This becomes, $\cos Z=\sin 20°\ 20' \sec 39°\ 47' \sec 52°\ 50' - \tan 39°\ 47' \tan 52°\ 50'$.

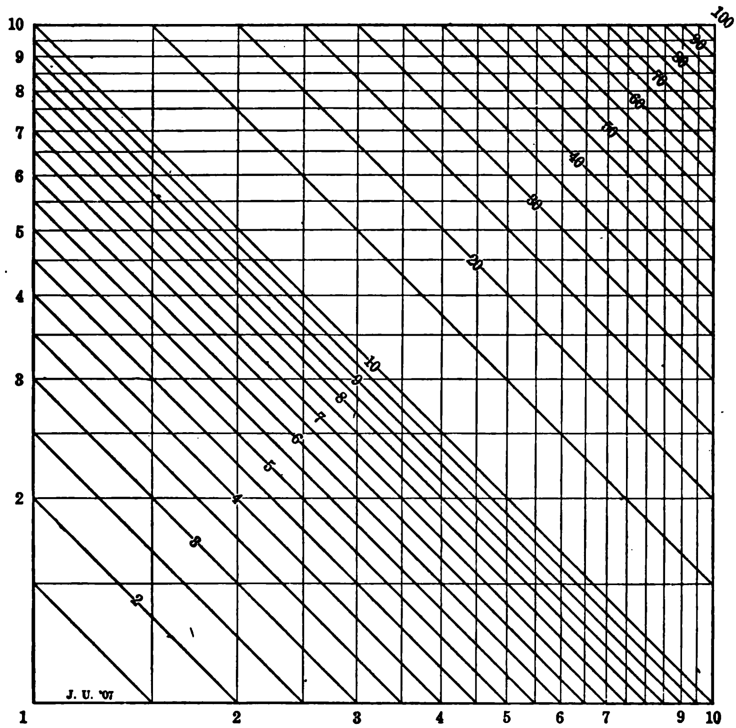


FIG. 44. — LOGARITHMIC CROSS-SECTION PAPER.

'On Plate *A*, Fig. 45, find sin 20° 20′ between the vertical lines for 20° and 21°; the intersection of these lines and the horizontal line for sec 39° 47′, just under sec 40°, will give us the product of sin 20° 20′ and sec 39° 47′. We do not as a rule care to know the exact value of the product, though it can be obtained by reading the value of the line drawn at 45°. Follow the inclined line which is very close to 0.45 (or exactly 0.4521) to the intersection with the bottom horizontal line, and thence along a vertical

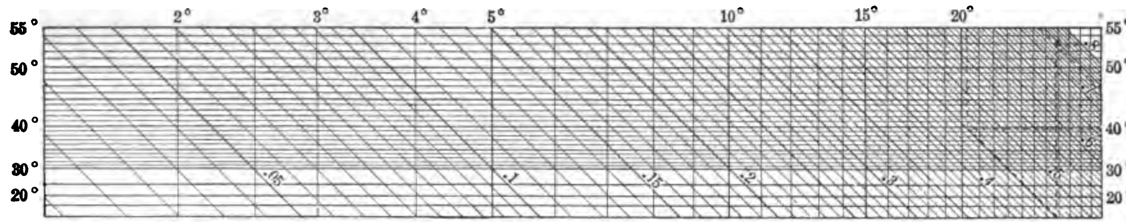


PLATE A.

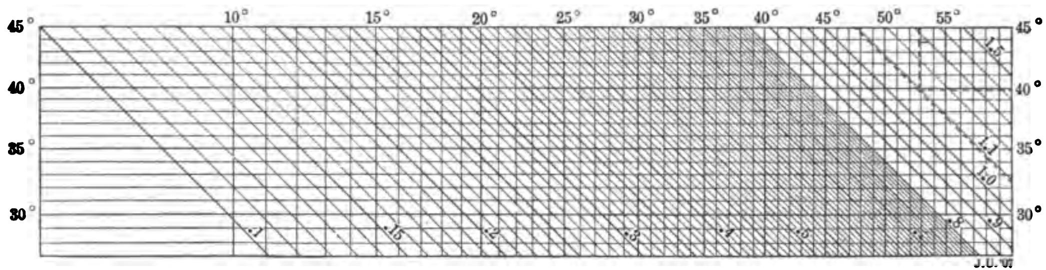


PLATE B.

FIG. 45.—LOGARITHMIC TRIGONOMETRIC PAPER.

line to the horizontal line representing the sec 52° 50′, which is between sec 52° and sec 53°. At the point read on the inclined line the final product 0.7484, between 0.7400 and 0.7500.

'For the second part on Plate 45*B* where the vertical line of tan 52° 50′ intersects horizontal line tan 39° 47′, find on inclined line 1.0984 between 1.0000 and 1.1000

$$\begin{array}{r} -1.0984 \\ +\underline{0.7485} \\ -0.3499 \end{array} = \cos 69^\circ 31', \text{ or the course of}$$

the sun.

'The second part is simple enough and the result is seen at a glance. The first part involves two operations, in every way the same as when a runner is used on the slide rule. When a number of observations are made at the same time the product is constant, and when we have once determined sin d by sec l we can multiply this product by any number of values for sec a, with no effort. Then, in Plate *B*, Fig. 48, having found our constant latitude, we can multiply by any number of altitudes almost at a glance.

'The plate used with this article was originally constructed on a scale of 400 units, or divisions, to the inch, and from that reduced to its present size. The writer has obtained very fair results with a scale of 200 units to the inch, carefully made. For practical work, and results to one minute of arc, the scale should be not less than 100 divisions to the inch. This makes a width for each plate of about 30 inches. The length is not important as the plate may be comprised of overlapping sheets. On the slide rule and on logarithmic cross-section paper, the divisions are in multiples of one thousand, according to the logarithmic value of either numbers or trigonometric functions. In Plate *A*, we begin a little to the right of the vertical line for 5°, or where the inclined line strikes the lower horizontal line, indicated by *X*. As log $l=0$, we here draw the inclined line for 0.1. On the lower horizontal line, on each side of the assumed 0 point, lay off distances corresponding to the logarithmic sines of the declinations required. 50° 45′ will be very nearly at the 0 point, since the sine 5° 45′ is about 0.1, its log being 9.000+; 6° will be at 19 divisions of the scale on the right (log sine 6° = 9.019); and 5° at 0.9402, or −59.8 divisions on the left (9.0000 − 8.9402 = 0.0598). Unless a very long table is constructed it is not easy to get the declinations for less than, say, 2°, though with the proper length it is possible to

get as small a declination as we please. If a smaller declination is required it might be well to construct a table on a much smaller scale for this part of the plate. Having platted on our logarithmic sines to 23° 30′ (and these may be platted on any horizontal line) the vertical lines are then drawn as close together as we wish. To obtain the divisions for the lines inclined at 45° we lay off on the lower line, or on any line distant 1000 divisions from it, the distances corresponding to the logarithms of the numbers required; thus we have seen 0.1 at *L*, our starting point, and 0.2 will be 301 divisions to the right, and 0.09 will be at 0.954, or -46 divisions to the left, since the log of $0.2 = 9.301$ and the log of 0.09 is 8.954. The same starting point is, of course, used for the sines and numbers. Any number of inclined lines may be drawn, as shown on the plate, from the platted points. In exactly the same way, from the lower horizontal line as our starting point, the logarithmic secants for 0° to 55°, or more if required, are platted, and the horizontal lines are drawn.

'For Plate *B*, Fig. 45, we plat the logarithmic value of the tangents exactly as above, using the upper left-hand corner as our starting point, which is nearly 5° 43′ (tan 5° 43′ = 1.00, log 0.1 = -1.0000 for the vertical lines), and as 1 or tan 45° for the horizontal lines. Thus 10° will be platted 246.3 divisions to the right of our starting point, or the log tan $10° = 9.2463$, and tan 40° for our horizontal line will be platted 923.8 (calling our upper horizontal line 1000) or 40° will be -76.2 divisions, or below our upper horizontal line. The inclined lines must be laid off in the same way as before, but from the upper horizontal line. Then 0.10000 will begin at our starting point at the upper left-hand corner, and 1.000 will be a thousand divisions to the right of 45°. It must be clearly borne in mind that the inclined lines must always start, in the use of logarithmic cross-section paper, from a horizontal or vertical line at some logarithmic value of 0.1000, 1.0000, 0.01000, etc. In the case before us we can use only the horizontal lines to advantage. This can be clearly seen by an inspection of Fig. 44. By proportionate divisions, however, the inclined line may be drawn from another initial line, but extra work is necessary.

'Considered from a graphical standpoint only, this method has the great advantages of all logarithmic methods, in that a table is very quickly and easily constructed. We have to draw only three sets of lines, and these are all in the easiest directions in

which a draughtsman is ever required to draw lines. The engineer need not draw the whole table at once. Just as the map of the property is divided off into squares before much surveying is done, and the details of the square are filled in, perhaps many years afterward, so here we may draw the skeleton outline, say to degrees, and afterward fill in as required. For the engineer working within narrow limits of latitude, a table for tan l would be simply a long ribbon, and could easily be carried into the field. By proper attention to the possible altitude and latitude in advance, part of the upper table could be easily traced and carried into the field for the first part of the formula. The disadvantages of this method are those inherent in all logarithmic methods, and consequent unequal accuracy in different parts of the table.'

Property Lines. — In mineral properties, the property lines have, of course, always been carefully established, and permanent monuments erected, by the United States Deputy Mineral Surveyor, who surveyed for patent. In coal properties, this is frequently not the case. This should be one of the first things done when surveying a coal property, for it has an important part in the laying out of the mine. This is also necessary in order that lawsuits over boundaries may be avoided.

As the running of surface boundary lines is understood by all surveyors, and is explained in every text-book upon plane surveying, it will not be discussed in this place. The pamphlet of directions to deputy surveyors from the General Land Office is explicit upon rerunning land lines. The pamphlet to deputy mineral surveyors will make clear any question about the boundary lines of a mineral claim. Underhill's 'Mineral Land Surveying' is specially recommended for this work.

Surveying Boundaries of Mining Claims. — 'Be it enacted, That section 2327 of the Revised Statutes of the United States be, and the same is hereby, amended to read as follows:

'Sec. 2327. The description of vein or lode claims upon surveyed lands shall designate the location of the claims with reference to the lines of the public survey, but need not conform therewith; but where patents have been or shall be issued for claims upon unsurveyed lands, the Surveyor-General, in extending the public survey, shall adjust the same to the boundaries of said patented claims so as in no case to interfere with, or change, the true location of such claims as they are officially established upon

the ground. Where patents have issued for mineral lands, those lands only shall be segregated and shall be deemed to be patented which are bounded by the lines actually marked, defined, and established upon the ground by the monuments of the official survey upon which the patent grant is based, and surveyors-general in executing subsequent patent surveys, whether upon surveyed or unsurveyed lands, shall be governed accordingly. The said monuments shall at all times constitute the highest authority as to what land is patented, and in case of any conflict between the said monuments of such patented claims and the descriptions of said claims in the patents issued therefor the monuments on the grounds shall govern, and erroneous or inconsistent descriptions or calls in the patent descriptions shall give way thereto.'

Bibliography. — Education of Mine Surveyors in Prussia, *Col. Guard.*, February 17, 1899; The Qualifications for a Mine Surveyor, *ibid.*, July 6, 1906; Calculations of a Survey, *ibid.*, July, 1905; General Practice in Mineral Lands, *ibid.*, November, 1896; The Real Error of a Survey, *Mines and Minerals*, February, 1900; Alignment of Tunnels, *A. S. C. E.*, vol. xxvii, p. 452; Laying Out Curves Underground, *ibid.*, vol. xxiii, p. 22; Meridian Drinker's Tunneling, *Mining Reporter*, January 3, 1907, p. 919; Astronomical Observations for Meridian, *ibid.*, January 3, 1907; Coordinate Surveying, *T. A. I. M. E.*, vol. xx, p. 759; Improved Methods of Measuring, *ibid.*, vol. ii, p. 219.

III

UNDERGROUND PRACTICE

Stations

Underground stations are made in a great variety of ways according to the length of time they are to be used, the position they occupy, and the ideas of the man who has the work in charge.

Some of the more common stations are: (1) Conical hole, (2) nail, (3) spad, (4) staple, (5) crew-eye, (6) screw-hook, (7) wire or cord held in hole by plug, (8) hole and clip, (9) floor stations by rivet, (10) sheet tin with cross-cut, set over hole in plank.

For temporary stations a nail driven in roof or floor, a scratch on a smooth surface, or the mere transit position is sufficient. For carrying a traverse down a highly inclined shaft a medium-sized finishing nail is very convenient. This is driven into the side of a plank secured across the shaft so that it may be sighted from both above and below. This plank must, of course, not be used as a support for either transit or transit man, and its position must be selected so that the instrument may be set up over it; or the nail may be driven into the hanging wall-plate and the transit set up under it if the dip of the shaft is low enough to permit.

Some old descriptions of stations describe one as being simply a conical hole drilled into the roof of coal mines. To suspend a plumb-bob from this station, a triangular-shaped piece of sheet iron, with a notch in the apex of the triangle through which the string passes, is held into the hole by means of a wooden handle. Besides being too inconvenient, this is also too inaccurate a method to be considered.

Another device which has been used in coal mines consists of the following: A hole half an inch in diameter is drilled vertically into the roof, and into it is slipped a steel spring which grasps the sides of the hole with force enough to sustain the weight of the plumb-bob. The clip is made from a thin band of iron bent into a loop and so arranged that the point of suspension of the plumb-bob

lies in the axis of the cylindrical hole. While by this method one escapes the possibility of having the station ruined by mischievous mule-boys or pulled out by miners to be used as a lamp pick, its accuracy is to be questioned, and it certainly would fail in a poor roof.

A majority of the mines of the United States are using punched horseshoe nails known as 'spads.' The head of the horseshoe nail (about number 8) is hammered flat and a hole punched (*h*, Fig. 46) through it. This is smoothed off and the plumb-bob suspended from the round punch-hold; or, as is done at the Portland

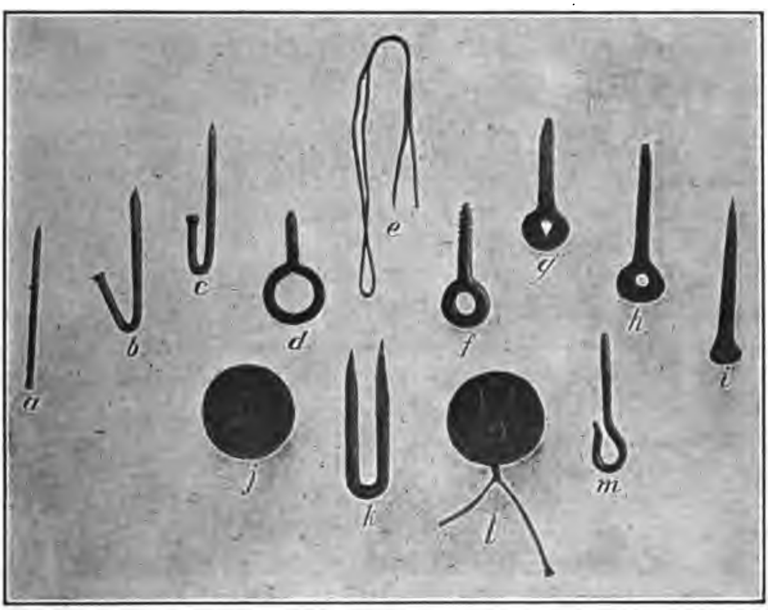


FIG. 46. — UNDERGROUND STATIONS.

Gold Mine, Cripple Creek, the bottom of the hole is filed (*g*, Fig. 46), in a V so that the plumb-bob string occupies exactly the same place every time the station is sighted.

These spads are usually driven into a wooden plug in a drill hole in the roof. The size of the hole varies from 1½ inches in diameter and 3 inches deep in coal mines, to half an inch in diameter and 1½ inches deep in hard crystalline rocks. The plug is slightly larger than the hole, and of a length so that when driven in its end is just flush with the rock surface.

Instead of spads, some engineers use screw-eyes or staples (*d* and *k*, Fig. 46), with or without a filed notch. Either a spad, screw-eye, or staple requires that one end of the plumb-bob string be passed through the opening and then fastened again below. To avoid this inconvenience, a hook of small wire may be fastened to the string by a loop and the hook-end inserted into the eye of the station.

To avoid the eye station, some engineers use screw-hooks (*m*, Fig. 46), or a nail bent till a sharp V is formed (*b* and *c*, Fig. 46). The latter is very convenient, accurate, easily formed and cheap. To hang a plumb-bob from these, the loop of the string is simply passed over the point of the hook, and if a V be filed at the bottom of the bend, it must occupy the same position every time it is hung.

Instead of driving a station into a wooden plug, the ends of a loop of wire (*e*, Fig. 46) may be held in the hole and the plug driven in to hold it. The loop of wire left outside is then used to support the plumb-bob.

While a roof station should usually be placed in a plug in a hole in the roof, it frequently becomes convenient and even necessary, to drive the station into the mine timbering. The accuracy of these stations depends entirely upon the permanence of position of the timbering. Each engineer must judge of this for himself, and when reoccupying old stations in timber, their position should be checked up.

Floor stations are to be avoided where possible; the best are probably a punch-mark on the rail, but nails or tacks driven in a notch cut into cross-ties or metallic stubs set into the floor-rock are sometimes used. These must always be checked before reoccupying to be sure that their position is the same as when they were set.

One writer [1] suggests the use of a small rail spike driven into a plug. To hold the plumb-bob string a slit is sawed into the head of the spike.

Station Marks. — The location of the station is generally made apparent by some means. In coal mines, this is often done by means of a daub of white paint on the rib opposite the station. In metal mines, which are not so dirty, the stations are more easily found and often are not marked except by the station number.

[1] In the *Iowa Engineer*, September, 1907.

Where the number is marked on the wall or roof, it is usually done with white lead or dutch white (a mixture of lead carbonate and barium sulphate) paint. Chalk is sometimes used. Sometimes the station number is scribed into the mine timbers, or even chiseled into rock walls.

It is becoming usual to use station tags. These are circular discs or squares (Fig. 46) of brass, lead, or zinc. The tag is punched for nails and often for the station spad, and the number of the station is stamped upon its surface.

Where different kinds of stations, as transit and level bench marks are used, a geometric symbol may be painted near it to designate it (page 203).

Where numbers are put on with paint, it is necessary to carry a short, stiff brush (round, 1-inch in diameter, is good) and a small tin can containing enough paint for the day's work. This quickly becomes foul from the dirt of the surfaces painted, and a fresh lot becomes necessary. Where the walls are very wet, paint will not stick, and some other method of marking must be employed.

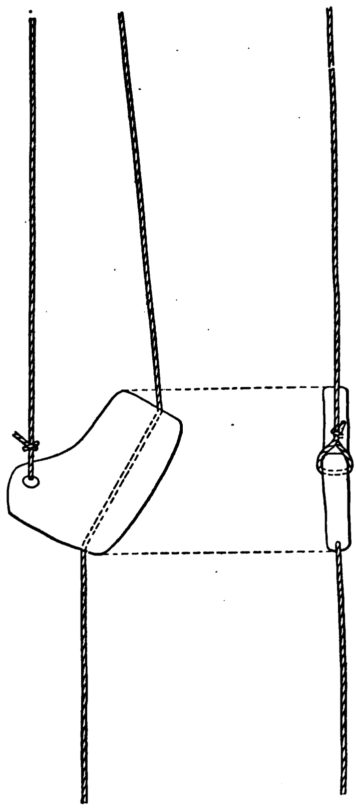


FIG. 47. — PLUMB-BOB STRING ADJUSTER.

Numbering of Stations. — In almost all mines it is customary to give each station a separate number, but in some it is not done.

In coal mines it has frequently been customary to use the railroad system of numbering stations, i.e., in hundreds of feet plus the decimal part of a hundred distant from the zero station. Where all the mine workings are upon one level, this system seems to be very satisfactory.

Along a main entry running east and west, side entries are

distinguished as 'second south' or 'ninth north.' Stations on the main entry are numbered consecutively without suffix or prefix. On the side entries, numbers 9 N. 31, or 3 S. 45 would mean station 31 on the ninth entry to the north, and station 45 on the third entry to the south. By this method the surveyor is able to go directly to any station he may wish, or picking up any station by number underground, he locates himself at once.

In mines where the workings are upon several levels, as are most metal mines, a number in no way relating to the exact position in the mine is given to each station. In most mines this

FIG. 48. — TUNNEL TRIVET.

is done by means of some system; as, for instance, all numbers from 0 to 100 are reserved for surface stations, from 101 to 200 for stations on the first level, and from 801 to 900 for stations on the eighth level. Again, it is sometimes convenient to number stations 603 E., or 925 W., reading station number three, east of the shaft on level number six, or, the twenty-fifth station to the west of the adit on level number nine.

At some of the large mines, however, no system is used in numbering the stations. Care is taken that no duplicates are used, but one is unable to find the station from a knowledge of its number alone. The Portland Mine of Cripple Creek uses this method, and some of the Butte, Montana, companies go farther

and use one series of stations for a number of different mines. Others number the stations consecutively as they are put in.

In some cases, the station is not numbered or marked underground at all. In the notes and upon the maps it is given a num-

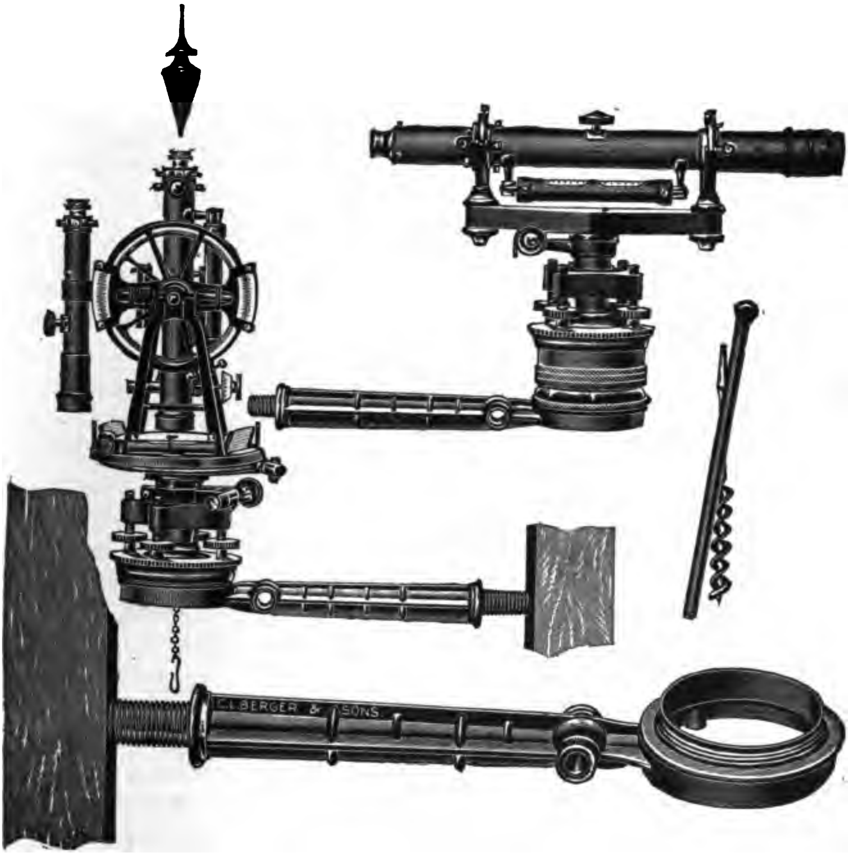


FIG. 49. — INSTRUMENT BRACELET.

ber, but a surveyor must know the mine, and must constantly refer to the index and ledger in order to use old stations.

It is very probable, however, that if it could be readily done, these mines would adopt some system whereby the station number would give a clue to its location. But having worked for years under one method, it is no easy matter to change, and the old method is continued in use.

Where a mine is laid out by coördinates, it becomes possible to give each station a number which gives its location exactly. Suppose, for example, that a station is set on the sixth level, 64 feet east of the point of origin and 437 feet north. Its number could be 6–640–437. The only objections to this system are, first, the necessity of calculating the coördinates of a station before it can be numbered; and, second, the multiplicity of figures used in the number. The first objection is a real one, but the presence of several figures on a number tag is frequently a benefit. After being in place for years, the tags are frequently corroded so that the presence of several figures is a welcome aid to identification.

Setting up the Transit. — If the station is in the floor, the transit is set up, as in ordinary surface work, by bringing the plumb-bob over the station. If, as is almost always the case, the station is in the roof, one of two methods may be used.

The first method, and the one probably most used, is to hang a plumb-bob from the station to near the floor, and place immediately under it a temporary point over which the transit is set in the ordinary way. The temporary point on the floor can very readily be made by driving a small nail through a lead block, then turning the block so that the point of the nail may almost touch the point of the plumb-bob hanging from the station. The weight of the lead block tends to prevent any movement of the nail point. The chief objection to this method is the chance of a slight movement of the floor point after the plumb-bob is removed, and before the transit is set up. Any slight movement would probably not be noticed, and would therefore go uncorrected.

The second method is that of setting up under the station direct. Almost all mining transits now have the center-point marked upon the top of the telescope. This point is brought immediately under the point of the plumb-bob hanging from the station. To do this, the transit must be set up as close to the true point as possible, and leveled up, then adjusted by means of the sliding head and again leveled to see if the center of the transit is still under the point of the plumb-bob. In setting under a point, the instrument must be level, or the center-point marked upon the top of the telescope will not be in vertical line through the center of the circle. Although this method necessitates the leveling of the instrument and of the telescope, and requires, therefore, a little more time, per-

haps, one can always tell by a glance whether the transit is truly under the station or not. In setting up under a point, a patent spring plumb-bob, which can be readily raised or lowered, will be found to save considerable time. Without its use, one usually has to adjust the plumb-line at the station several times.

Fig. 47 shows an easy method to adjust a plumb-line, either for use as a foresight, or as a point to set under, or even as the plumb-line under the transit. A piece of heavy sole leather is best, but an ordinary trouser button may be pressed into service.

FIG. 50. — HOLDING SIGHT.

Sighting in the Dark. — In order that the plumb-line or nail head may be visible, it is necessary to illuminate it. An ordinary candle, or a 'Cousin-Jack,' or a miners' oil lamp may be held in front of and to one side of the string. This illuminates the front of the string and is all right for short sights. For longer sights, or where the air is not clear, it becomes necessary to illuminate some translucent material, such as oiled paper, tracing cloth, or ground glass held behind the string (Fig. 50). The string then appears as a black vertical line across a white face. It is often difficult to distinguish between the vertical wire and the plumb-line. One must be certain that the two are brought together.

At Butte,[1] an ingenious candle plummet (Fig. 51) is being used. In the coal mines of the east, a plummet lamp (Fig. 53) has long been in use. The point sighted is the top of the wick. Where the three-tripod method is used in coal mines, the wick of the tripod lamp is sighted unless a special slit target is used in front of the flame.

The writer has used a device for illuminating the plumb-line of the backsight which is easily made, easily carried about, and saves much running back and forward of the assistant. A three-

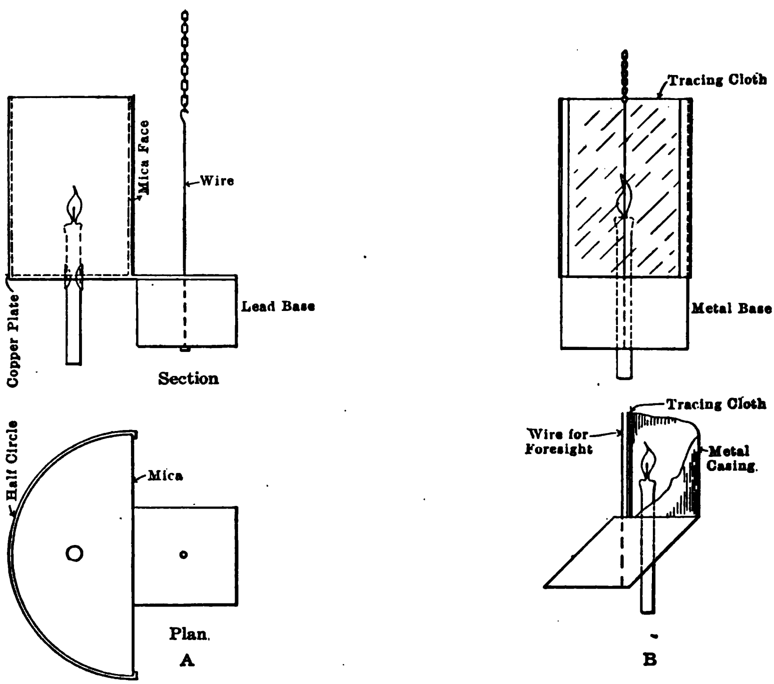


FIG. 51. — BUTTE BACKSIGHTS.

inch circular hole is cut in the bottom of a large tomato can. The bottom of another can is cut out and made to just slide inside the first can, and a three-inch hole then cut in it. A piece of tracing cloth is laid into the bottom of the can and the second can bottom then forced snugly in to hold the tracing cloth. A hole to admit a candle is punched about an inch and a half back of the bottom

[1] Described page 193.

and another small hole near the lip of the can. This can is now mounted on a camera tripod by means of the tripod screw, and a nut to fit it (Fig. 52).

This device is set up close to the string after the plumb-bob comes to rest, and is not affected by draught or dropping water. The transit man may then backsight at any moment and will find the tomato can 'holding sight.' The Butte candle plummets are

FIG. 52. — TIN CAN BACKSIGHT.

probably more convenient, but the writer had never heard of them at the time the above device was used.

Not only must the backsight be illuminated, but the telescope cross wires as well. The most simple method of doing this is shown in Fig. 1. A card is held to one side of the telescope, and projecting in front of the objective, by a small rubber band. A candle or lamp held to one side and in front will cause the cross

hairs to become plainly visible. Manufacturers of surveying instruments put several kinds of reflectors (Fig. 54) upon the market. An objection to some of them is that they cut off some

FIG. 53. — PLUMMET LAMP AND PLUMB-BOBS.

of the light coming from the foresight, and all the light obtainable is needed in underground work.

In some instruments, especially the heavy tunnel theodolites made for extremely accurate tunnel work, the horizontal axis of the telescope is made hollow and a lamp is mounted on the side of the instrument in line with the hole.

The instrument man must also have a light to illuminate the verniers while reading them, and to light his note-book while recording his readings. The ordinary candle or miners' oil lamp can be, and is, much used. The oil, grease, and smut from them are objectionable, however. The small electric dry-battery lamps, commonly used by gas inspectors, are very handy and are much used. The difficulty in obtaining new dry batteries for them is a serious objection, however, in many localities. Within the past few years, there have been small acetylene lamps placed on the market which serve the transit man's purpose admirably. They are light and clean, and the carbide can be obtained in quantity and keeps in good condition till used.

FIG. 54. — CROSS-WIRE REFLECTOR.

Bibliography: *Underground Practice.* — Anthracite Survey Practice, *Eng. and Min. Jour.*, February 11, 1904; Surveying Party, *ibid.*, August 25, 1904; Station Numbering, *ibid.*, September 8, 1906; Surveying of Pratt Mines, Ala., *T. A. I. M. E.*, vol. xix, p. 301; Iron Mines of Virginia, *ibid.*, vol. xx, p. 96; At Center Star Mine, *Canadian Min. Rev.*, July, 1905; Possibilities of Gunnison Tunnel, *Eng. Rec.*, October, March, 1903; Mine Surveys, *Queen's Gov. Mining Journal*, September 15, 1905; General Underground Methods, *Min. Rep.*, September 29, 1904; In the Rocky Mountains, *Mines and Minerals*, vol. xix, p. 241; Backsights, *ibid.*, August, 1904; By Transit, *ibid.*, March, 1900; General Methods, *ibid.*, vol. xix, p. 187; Coal Mine Methods, *Colo. School of Mines Bulletin*, vol. ii, p. 4; Stations in Poor Roof, *Mines and Minerals*, vol. xix, p. 247; Stations: Number Scheme for, *M. and Sci. Press*, October 24, 1903.

IV

CARRYING THE MERIDIAN UNDERGROUND

THE meridian may be carried underground by one or more of the following methods according to the conditions at the particular mine being surveyed. In case it is possible, a second method should be used as a check upon the correctness of the first. These methods are tabulated below in order of the probable accuracy of each.

(1) By traverse of two or more adits or slopes.
(2) By means of plumb-lines in more than one shaft.
(3) By traverse of one level or slope.
(4) By means of two or more plumb-lines in one shaft.
(5) By means of transit traverse down a shaft.

TRAVERSE OF TWO OR MORE OPENINGS

Where a mine is entered by adit or slope, a traverse run by ordinary method carries the meridian with it. Where a mine is entered by one adit, there is almost always a shaft or another adit, and the traverse may be closed for a check.

This method is evidently the easiest and gives results which are less apt to be in error for the reason that there are no peculiar difficulties to be overcome; the traverse can usually be closed and if an error has been made, it is known at once.

Where the openings are an adit and a vertical shaft, a wire and heavy plumb-bob are lowered through the shaft. A traverse is then run over the surface to determine the position of the wire at the collar of the shaft. A random traverse is then run in through the adit to the plumb-wire and the bearings of the different courses of the traverse calculated.

PLUMB-LINES IN MORE THAN ONE SHAFT

Plumb-lines in two or more shafts determine the meridian underground in very much the same way that a traverse in an

adit and plumb-line in one shaft does. A traverse over the surface determines the positions of the wires, and a random traverse between the wires underground gives the bearings of the courses.

Any two openings to the underground workings are always used in preference to carrying the meridian through one single opening by any method. Where the meridian has been carried down by any method through one opening, it is almost always found to be in error when a second opening, or a connection with other workings is made; although the error is surprisingly small in some cases.

A rather costly but novel way of securing a long base-line for the plumb-lines was used in the case of one of the tunnels driven under Lake Michigan by the city of Chicago, in an effort to secure pure water.

'To aid in placing the lake-shaft beyond all doubt in the line of the tunnel a six-inch tube was sunk some 280 feet eastward of the land shaft after the masonry had been carried beyond that point. By plumbing up this tube, a range of great accuracy was, of course, secured.'[1]

Plumb-Wires

The wires used for plumbing shafts should be as small as will hold. A small wire is desirable because it is easier to line in on, and because it is not so readily affected by falling drops of water or by air currents. On the other hand, one does not care to risk breaking a wire, and the elasticity of the smaller wire is more noticeable.

When plumbing the Tamarack No. 5 Shaft[2] a number 24 piano wire 4250 feet long stretched 15 feet when 50-pound weights were substituted for 8-pound weights. When these 50-pound weights were immersed in engine oil, the buoyancy of the oil allowed the wire to lift the weights 25 inches.

There is considerable variation in the size of wires and weights used at different mines. The Boston and Montana (Butte) engineers use number 18 copper wire with an 11- or 12-pound weight. At Copper Queen, a number 7 steel music wire with a 41-pound weight is used, and at the Portland of Cripple Creek, a

[1] Drinker's 'Tunneling,' p. 919.
[2] *Mines and Minerals*, vol. xxii, p. 248.

number 20 copper wire with a 7½-pound iron window weight is used. The Calumet & Hecla uses a number 22 steel piano wire with an 11-pound weight.

The steel wire is smaller for equal strength, but is not so easily obtainable, as a general thing. The copper wire is not so apt to remain bent or kinked as is the steel. A number 18 copper wire will sustain a 12-pound weight to a depth of 1200 feet, but for a greater depth, or with a heavier weight, a larger copper wire, or a steel wire, must be used. Where a number 20 copper wire is not strong enough, it is probably better practice to use steel.

To Lower Wires in Vertical Shafts

In shallow shafts, it is practicable to attach a light weight to the end of a wire and lower it directly off a reel. This is impossible, however, for anything but very shallow shafts, for the weight will catch in the timbering.

Where a cage is installed, it is convenient to attach the end to the top of the cage and run the wire off a reel at the surface as the cage is lowered. When the bottom is reached the end of the wire may be attached to the side timbering and the cage hoisted clear if desired. It is best to have the reel at the surface where the hoisting engineer can see it, for if the reel is carried on the cage and the wire fails to run freely, it is almost sure to be broken before the hoist man can be signaled to stop. Several hundred feet of loose wire dropping down upon the top of the cage makes a most troublesome tangle. After such an accident, the wire must be thrown away, for the kinks in it will never come out.

Where wires are to be lowered through very deep shafts, it may be best to use a large wooden frame, pointed at each end and large in the middle, to pull the end down. Such a frame, 10 or 12 feet long and 4 feet in diameter at the middle, cannot catch on the timbering.[1]

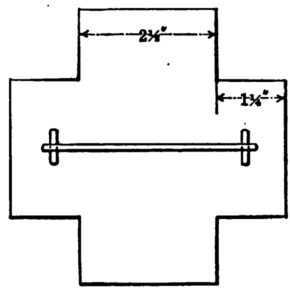
A simple device which we find of great advantage in plumbing shafts is, to have in the wires on the side toward the transit, three links from an ordinary trace chain. Cut the wires about 4½ feet above the end of the weight and fasten the three links between these two ends.

[1] *Mines and Minerals*, vol. xxii, p. 247.

This allows the wires to twist and turn as they please, and one of the links will always be in such a position that you can sight through it to the wire beyond, and feel certain that your transit is on the proper line, and that you have seen both wires.

Plumb-Weights

The weights used vary as greatly as do the wires. One engineer uses a winged weight of cast lead or iron (Fig. 55); another uses a couple of old rusty flat-irons. One uses a large plumb-bob with wings of sheet zinc fitted into vertical slots in it, and another uses window weights. The makers of surveying instruments put plumb-weights upon the market, but a window weight or a flat-iron answers the purpose just as well.



Cast Iron 25 Lbs.

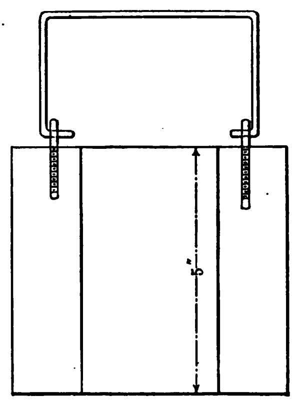


FIG. 55.—CAST METAL PLUMB-WEIGHT.

The weights are usually swung in water or oil in order to more quickly stop the vibrations of the wire. One must remember that the vibration period of so long a pendulum may be minutes. Considerable time is required for it to come to rest.

In some cases, falling water or air currents will prevent its coming to rest, and it then becomes necessary to find the centre-point of its ellipse of swing. To do this, one of several methods may be used. The quickest is to simply set the telescope so that the wire is estimated to swing an equal distance to either side of the vertical cross-hair. This is, of course, an approximation, but may be very accurate. To find the centre of swing accurately, it is necessary to note and mark the end-points of each swing. This may be done by nailing strips of wood about the wire just outside the end-point of the wires' swing. These strips will represent straight

lines tangent to an ellipse. The centre of the ellipse is the true position of the wire. Other methods are described in *Colliery Engineer*, September, 1895, p. 31; and in *Engineering and Mining Journal*, January 12, 1893, p. 81.

Two-Wire System

Two wires are most generally used where it becomes necessary to carry the meridian down a vertical shaft which has no underground connections with any other opening.

The wires are, of course, hung as far apart as is possible in order to secure the greatest length of base. They are either hung in a predetermined plane by lining them in with the transit as they are placed, or after hanging them their plane is determined by setting the transit up in it, or by triangulation methods.

The same procedure is followed underground to take the meridian off the two wires. Where it is convenient to set the transit in the plane of the two wires, most engineers prefer to do so. Where the underground stations will not permit of this, the triangulation method must be used.

The distance between the two wires as measured at the bottom must check that as measured at the top. In case the measurements do not check, the probability is that some obstruction in the shaft causes one of the wires to hang out of plumb. In case, however, that a search fails to find any such obstruction, some other explanation is necessary. If the plumb-weights used are of iron, it may be that magnetic influences disturb them. Instances of this kind have been proved. If so, the substitution of lead weights for the iron will cause the discrepancy in measurements to disappear.

Sometimes, however, the wires fail to hang perpendicularly on account of air currents in the shaft. Air rushing in from levels on one side of the shaft may push one wire in toward the other. If it is pushed directly toward the other, the distance apart of the wires will be affected, but not their bearing.

It is known that air rushing up a shaft has a tendency to assume a corkscrew motion instead of traveling in straight lines. Now this phenomenon will cause one wire to diverge from the true plane in one direction and the other wire in the other direction. Their bearing, as determined from them at the bottom, will then evi-

dently be different from their bearing at the top. Their distance apart will also be affected, as each wire will tend to move from its true position along the tangent to a circle whose centre lies in the plane of the two wires.

If the rush of air, or splashing of drops of water, affects but one wire, it may be that the bearing of the bottom ends of the wires will be changed without affecting their distance apart. As this can be in no way known, it is evidently the chief objection to the two-wire system of plumbing shafts.

That the effect of air currents upon plumb-wires is considerable was shown by a survey [1] of the Tamarack Shaft No. 5, where the divergence at a depth of 4,000 feet was a tenth of a foot.

The Three-Wire System

By this system three wires instead of two are used. The three wires are not in the same plane. The position of each wire is found by triangulation at the top, and the meridian is calculated at any point below from a triangulation to the wires. It is not necessary nor customary to set the instrument up in the plane of two of the wires when this method is used. It may be done, however.

The advantages of the three-wire system are those affording a check upon work done. In the first place, if the three wires are in the same relative positions when measured at the bottom that they are at the top, it is unreasonable to suppose that air currents could have twisted them about so that the meridian taken off will be incorrect. And, second, the three wires give three possible triangles which may be solved for check results. With three wires it is always possible to set up the instrument so that two of them will be in position to give a triangle of good shape. Where the underground workings take off from the shaft in different directions, this is no small advantage.

The objections to the system are: the extra wire to hang, the use of one more compartment of the shaft for the third wire, and the time required to make the extra observations. The advantages certainly outweigh the objections. The certainty that any two wires lie in a true plane, rather than a warped surface is advantage enough to warrant the hanging of the third wire, even if it is not used in the taking off of the meridian at all.

[1] *Mines and Minerals*, vol. xxii, p. 247.

Four-Wire Method[1]

'We will suppose that in the shaft through which the meridian is to be carried, there are two hoistways, each 7 × 11 feet, with a 12-inch bunting between, as shown in Fig. 56. Now the first thing to be known is, which side of the shaft is the best adapted for setting up the transit. The point to be marked in the mines will

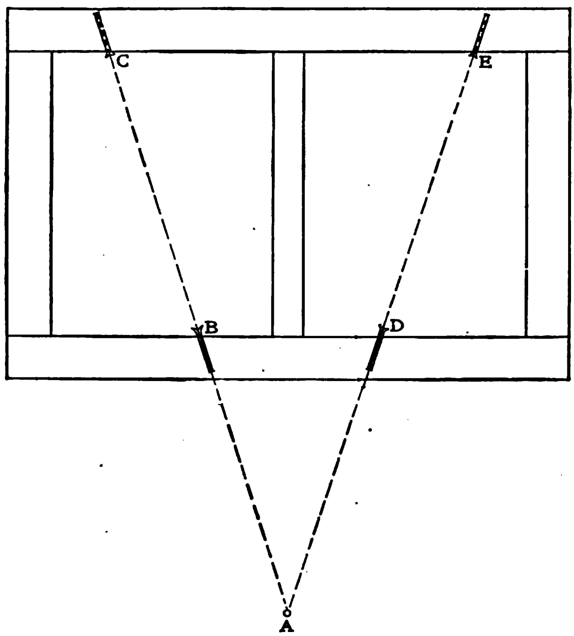


FIG. 56. — PLAN OF SHAFT STATION.

be vertically under the point on the surface, consequently the side with the widest opening leading from the foot of the shaft should be selected.

'Having carried the meridian to a point convenient to the top of the shaft, and having found that the south side of the shaft is the most accessible, with ordinary string determine the location of the point A, on which to set the transit, and from which to set the hangers for the plumb-lines; now mark with chalk on the timbers of the hoistways where the string crosses; these marks are, of

[1] George B. Hadesty, *Colliery Engineer*, vol. xvii, p. 24.

course, not accurate, but will be found to be quite a guide in setting the hangers. At the point A make a permanent station and carry the meridian thereto.

'The hangers to be used can be made from strap iron, $\frac{1}{2}$ inch thick by 2 inches wide, and about 16 inches long or longer if necessary, but not shorter.

'In one end of the iron have a jaw with a fine cut at the apex, or a drill-hole just large enough to contain the wire to be used for plumbing; in the 12 inches opposite the jaw-end have three countersunk drill-holes through which to fasten the hangers to the top of the shaft, by sheet-iron nails.

'In most shafts there is a space between the ends of the cage and the sides of the timbers, varying from 2 to 4 inches, so that in order to lower or hoist the cage to examine the wires after they are hung, the holes in the jaw of the hanger should be set in such a position that the wire passing through it will hang about midway in this space.

'On the north side of the shaft, fasten the hangers permanently over the chalk marks previously made, with the jaws pointing toward the point A.

'On the south side of the shaft, the outer end of the hanger can be fastened temporarily.

'Having carried the meridian to, and set the transit on, the station at A, take backsight, then foresight in the wire-hole of the hanger C, and set the wire-hole of the hanger B on the same line. Then, having recorded this course, foresight on the wire-hole of the hanger E and set the wire-hole of the hanger D on the same line; record this course, and the meridian to be carried into the workings below is established. Now measure carefully and record the distances A to B, A to C, and B to C; then the distances A to D, A to E, and D to E, and finally the distances B to D and C to E. The necessity of this is for a twofold purpose; first, for establishing the point A at the bottom of the shaft, and, secondly, for theoretical calculations in the office to prove the work.

'The transit party can now descend to the bottom of the shaft, taking with them four buckets of oil, the weights or plumb-bobs to be attached to the wires, and all the surveying instruments, leaving a responsible party on the surface to handle the wires. Having arrived at the bottom of the shaft, the cage may be

hoisted about 3 feet above the landing, and several planks thrown across the timbers on which to set the buckets of oil. The man on the surface may be signaled to lower one wire and fasten securely on top, passing it through the wire-hole of the hanger; now the weight may be attached and the wire adjusted to such a length that when sustaining the full weight of the plumb-bob the latter is sure to be free from the bottom of the oil bucket. The weight may be then inserted in the oil, using care not to put all of it on the wire with a jerk, but letting it go down slowly so that the wire may receive the full strain gradually and not so suddenly that it will snap in two. The same method may be followed until the four wires are in proper position.

'After the wires have been hanging a few minutes with the weights attached, the latter may move to one side or the other of the buckets. Watch this carefully and keep moving the buckets until the weights hang perfectly free, then leave everything alone until the wires become perfectly steady.

'If the wires have been placed midway in the space between the ends of the cage and the sides of the shaft timbers, the cages can now be hoisted and lowered, to allow an examination of the wires, so as to be absolutely certain that there are no projections to prevent them from hanging free and plumb. Care should be taken, however, to notify the hoisting engineer not to allow either cage to approach either landing closer than 3 feet, or the cages will tear off the hangers on the surface landing and crush the weights and buckets on the bottom landing.

'When the wires have apparently settled one may proceed to find the point of intersection, *A*, of the two lines at the foot of the shaft.

'Stretch a string along the wires *B C* and *D E*, using care to prevent the string from touching any of the wires, and with a plumb-line mark on the bottom of the gangway the intersection and compare with the same distances on the surface. If they compare closely, one can rest assured that they are settling nicely, and can proceed to carry the meridian from the wires to the desired point.

'Set the transit at the intersection just found, backsight on the wires *B C*, foresight on the wires *D E*, compare the included angle and the distances with the same angle and distances on the surface. If not exactly the same, then move the transit in the

direction necessary to increase or decrease the angle or distances, as the case may be.'

By Bent Line

An interesting string method for carrying the meridian down a shallow vertical shaft is described in *Mines and Minerals* of July, 1901, p. 559. Fig. 58 illustrates how the various lines, all

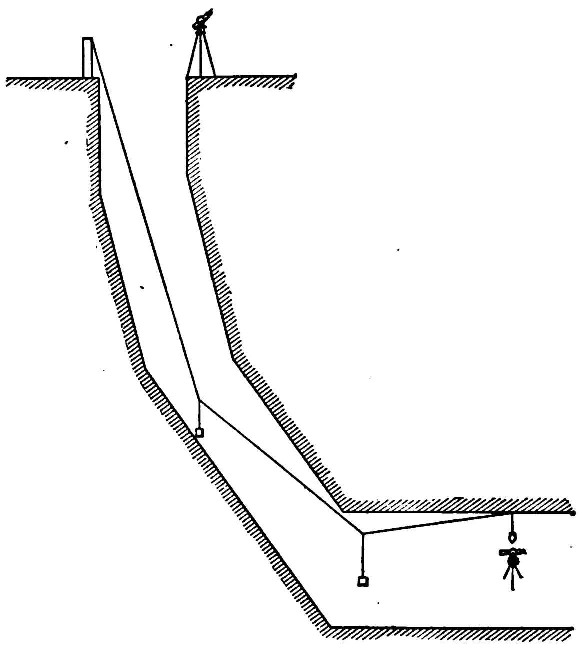


FIG. 57. — BENT LINE SURVEY.

being in one plane, take the meridian from a comparatively long base at the surface, and also give a long base below from which the meridian is taken by setting a transit in line with the two plumb-lines. This device does not, however, give position of a point, simply the direction of the line. To get the position of a point from which to measure, a single plumb-line must be lowered from the horizontal string.

The description of an interesting survey by means of bent lines, made by Prof. Mark Ehle, is given on page 212.

By Transit Sights

Where a shallow shaft is the only opening by which the meridian can be carried below, it may be convenient to establish a line by direct transit sight.

Either top or side telescope, inclined standard transit, ec-

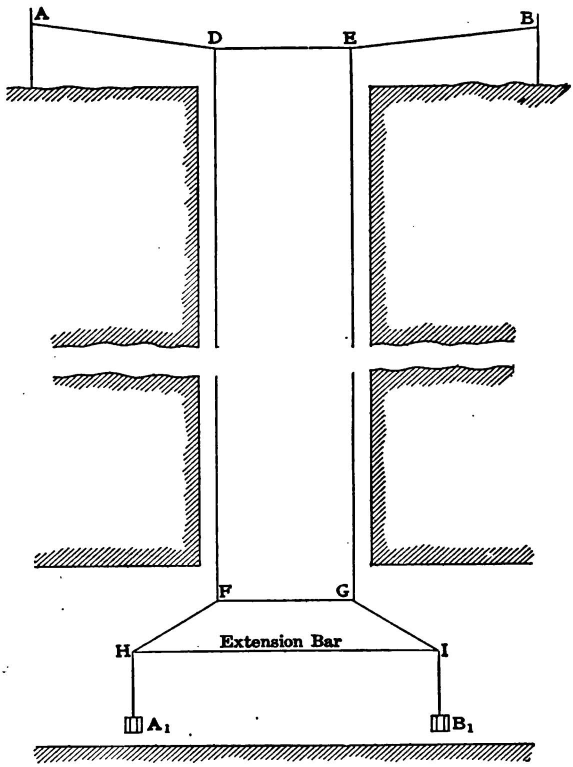


FIG. 58.—DOUBLE BENT LINE.

centrically mounted telescope or ordinary transit telescope may be used. In every case extreme care must be used in getting the instrument exactly level so that the vertical wire shall travel in a truly vertical plane.

With the top telescope, the line is swung down and points, as far apart as possible at the shaft bottom, are marked. By turning the plates 90° the vertical wire marks another vertical plane.

The intersection of these two planes is the plumb through the centre of the instrument.

With a side telescope, a plane parallel to, and equally distant from, the true plane is established on each side of the vertical plane. By swinging the plates 90° two more planes are established, which, together with the first two, make a square whose centre is the point directly under the centre of the instrument.

The ordinary transit [1] when set up in a leaning position gives the line of a true vertical plane but not a plumb-point, except as an angle of 90° from the horizontal position can be read on the vertical circle. This is, however, not accurate enough for anything but the very crudest kind of work.

Vertical Sights with Ordinary Transit. — When it becomes necessary to make a vertical sight and no auxiliary telescope is at

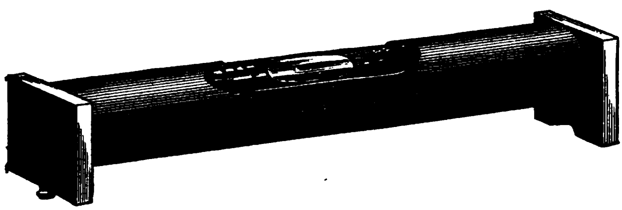


FIG. 59. — STRIDING LEVEL.

hand, it may be done by leaning the plates of the transit so that the line of sight, when vertical, will clear the plates.

If the sight is to be made down a shaft, the transit is set up with two legs shortened and resting close to the shaft edge. The third leg is extended and securely anchored. The instrument is then leaned over the shaft so that the plumb-line will fall inside the shaft.

When the plates are now tipped toward the shaft by means of the leveling-screws, the line of sight can be swung several degrees each side of vertical.

In order to have the line of sight cut a vertical plane, the horizontal axis of the telescope must be made truly horizontal in the inclined position of the instrument. This may be accomplished in several ways. First, and simplest, a striding level (Fig. 59) may be placed upon the horizontal axis and the plates swung till the bubble is in the centre of its run. Second, the plates may

[1] *Engineering and Mining Journal*, May 16, 1903, p. 749.

be moved till the line of sight will follow a plumb-line through about 45° of vertical angle; or, third, three points in a vertical plane may be established with the instrument leveled, and the instrument then inclined and centred in the determined plane.

By Traverse of Shaft. — In steeply inclined or crooked shafts it is often necessary to run a transit traverse. This is done exactly as in surface work or slopes. Extreme care and checks upon all work will give accurate results. The work is slow and tedious, however, and is to be avoided wherever any other method can be used. Platforms must be built across the shaft to support instrument and men, and timbers must usually be securely placed to hold station points. As all these timbers must be removed from the shaft no stations are left to serve as a check at a later time.

Work of this kind is dangerous, and special care is necessary in the selection of assistants. The author will carry a scar, made by a candlestick dropped by an assistant from a temporary staging 60 feet above, to his grave. The transit man must also remember that a misstep may land transit or man in the sump, perhaps hundreds of feet below. At first he will probably be able to think of little else, but familiarity always tends to make one careless.

Measuring Depth of Shafts

The hoisting rope is frequently measured to determine the depth of a shaft. On the same principle, a weighted wire is lowered into the shaft and measured as it descends, also measured again, for a check, as it is withdrawn.

A tape is stretched parallel to the wire, or rope, at the top, and its end-points marked on the wire. The wire is lowered the length of the tape and again marked, and so on till the first mark reaches the lowest part of the shaft to be measured. It is usually best to take the elevations off at the various levels by means of instruments sighted at a mark on the wire as it is lowered.

This method is good for shallow shafts, and a connection driven between levels on two deep shafts may meet accurately where the elevations have been determined by a measured wire in each case. It is, however, true that a hoisting rope, or a wire, is very elastic and stretches to a measurable extent. A wire 4000 feet long has been known to stretch 15 feet upon the addition of 40 pounds weight at the end, and to shorten 2 feet when this weight was suspended in oil. It is then quite evident that while concordant

results may be obtained by this method, the results are in error by equal amounts. For shallow shafts, where the elasticity of the wire would give a negligible amount of stretch, the method is quick and good.

By another method the shaft itself is measured. This is done by laying off successive lengths of the tape along the guide. One man must stand upon the cage, or bucket, and place a mark upon the guide opposite the zero end of the tape. A second man works from a seat clamped to the hoisting rope at the length of the tape above the cage. He holds the upper end of the tape opposite the mark made by the man at the lower end. He must do the signaling to the hoisting engineer.

A 100-foot tape is most frequently used, but a longer tape, if checked for length while hanging vertically, can be used and will save time and chance of error, as the number of times it is laid off is reduced. To mark the end-points, the author has used the long-spined large glass-headed library tacks. These can be pushed into a wooden guide with the bare hand. The head of the tack is not set close up to the wood and the tape can slide under it, so that the markings of the tape rest directly against the spine of the tack. An ordinary white carpet tack may be driven and the exact end-point marked upon the flat head with a centre-punch. The man at the lower end should leave a candle-snuff burning near the end-point to aid the upper man in finding it.

When measuring an inclined shaft, the measurements are usually made along the line of sight of the transit from one station to the next. Where the shaft is driven upon a fixed angle, it is quicker and easier to stretch the tape directly upon the skip rail.

Bibliography: *Transferring Meridian Underground.* — Plumbing Shafts on the Comstock, *Eng. and Min. Jour.*, vol. lv, p. 81; Plumbing Shafts in Montana, *ibid.*, vol. lv, p. 72; Plumbing Shafts in South Africa, *ibid.*, vol. lxxiv, p. 478; Plumbing Shafts by Leaning Transit, *ibid.*, vol. lxxv, p. 749; Plumb-lines at Tamarack Mine, *ibid.*, April 26, 1902; Transferring Meridian Underground, *ibid.*, vol. lv, p. 179; Plumbing Shafts at Hoosac Tunnel, *Colliery Eng.*, vol. xvi, p. 52; General Methods of Plumbing Shafts, *ibid.*, vol. xvi, p. 31; Wires of Plumbing Shafts, *ibid.*, vol. xvi, p. 32; Suspension of Wires, *ibid.*, vol. xiv, p. 92; Shaft Surveying for Tunnels, Vose's "Manual of Railroad Engineering"; Shaft Sur-

veying at Przibram, *Proc. Inst. of C. E. of Eng.*, vol. civ; Crooked Shaft by Plumb-line, *School of Mines Quarterly*, vol. xvi, p. 146; Severn Tunnel Survey, *S. M. Q.*, vol. iii, p. 272; Mine Surveying, *ibid.*, vol. iii, p. 269; Wires for Shaft Surveys, *ibid.*, vol. xi, p. 333; Prevention of Vibration of Wires, *ibid.*, vol. iii, p. 271; Plumbing Shafts of Croton Aqueduct, *Trans. A. S. C. E.*, vol. xxiii, p. 22; Cincinnati Water-works Tunnel, *Eng. Rec.*, vol. li, p. 234; Shaft Survey Iron Mines of Penn., *Trans. A. I. M. E.*, vol. vii, p. 139; Sperry Method of Plumbing Shafts, *ibid.*, vol. xxiv, p. 29; General Methods of Shaft Plumbing, *ibid.*, vol. xxi, p. 292; Underground Connection, *ibid.*, vol. xxiv, p. 25; Survey Measurements of Steep Drivages, *Col. Guard.*, September 24, 1897; Measure of Depth by Wheel, *ibid.*, April 20, 1898; Plumbing Shaft in Missouri, *Mines and Minerals*, July, 1901; Tamarack Shaft Survey, *ibid.*, vol. xxii, p. 247; Inclined Shaft Survey, *ibid.*, April, 1900; Meridian of a Survey, *ibid.*, December, 1900; A Quick Vertical Shaft Survey, *M. and Sci. Press*, August 25, 1906.

V

SURVEY OF ROOMS OR STOPES

THE main transit traverses in the survey of a mine are carried through the openings which are to be permanent; that is, the main haulage ways and headings, and the shafts and levels. Those openings which change in shape from time to time, and which are often filled up, or caved, after being worked out, are measured up by some method which is rapid, but not necessarily so accurate as are the main lines of the survey. These secondary openings are, of course, connected with the main survey, and all are mapped together.

In coal mines, a transit line is sometimes carried along the breast, especially in long wall work, but usually the rooms are measured by taking a side-shot up every third or fourth room and simply measuring the intervening rooms by tape through the break-throughs nearest the face. See page 206 for instructions issued to surveyors by the United States Coal and Coke Company.

In metal mines, it is sometimes necessary to measure, with considerable care, the openings from which ore has been removed. These measurements are frequently used as a basis upon which tonnage is estimated, and also as a basis upon which contract work is paid.

The Institute of Mine Surveyors (Transvaal) discussed ways in which these measurements were best made on the Rand. These papers occupy some fifty or sixty pages of their *Transactions* (Vols. II and III), and are well worth study, but are too lengthy to be reprinted in this volume. Any engineer who has to measure up contract work each week or two, especially on ledges similar to those of South Africa, can well afford to secure copies of these volumes of the *Transactions*.

In this country, those mines which have very large ore-bodies generally use the square-set method of timbering. This regular method of timbering has made possible the use of stope-books of

cross-section paper, and the sketching of the sets thereon instead of the actual taping of the openings.

NARROW STOPES

In narrow stopes where the square-set system of timbering is not used, it is customary to carry a transit-line up through a chute or manway, and then get the outline of the stope-face by radiating lines to points on the face. For this work, a pocket transit or compass is sufficiently accurate. The lengths of the lines and the vertical distance between stope-walls are measured with pocket tape. Where a stope is long, it may be best to carry an ordinary transit-line up the chute or manway nearest to one end, then the whole length of the breast and down the last chute to close on the nearest station of the regular mine survey.

If the surveyor is mapping the geology and the assay values, he must, of course, be careful to note all such during the stope-surveying. If he is mapping the geology, he had best have the shift-boss or foreman go through the stopes with him to point out any changes in geology which have been noticed during the breaking of the ore. The miners in each particular stope are usually able to bring things to the attention of the surveyor which he would of himself not notice.

METHOD OF KEEPING 'STOPE-BOOKS'

For maintaining an accurate record of all work done in the mines of the Butte district, a survey is run out on every level, beginning at the shaft, to the face of each crosscut and drift as the work advances, and is brought up to date once a month. Notes and sketches are made showing the timbering, angles, side-sets, stations, manways, and chutes, with their numbers. From these notes an accurate plan map is plotted in the office stope-book, showing the level with the timbers as they actually stand in the mine.

The field stope-book is about $10\frac{1}{2} \times 4\frac{1}{2}$ inches, and consists of sheets of cross-section paper of some convenient scale, each sheet being divided into squares of 1 inch by heavier lines. A scale of 20 feet to the inch has been found to give good results, as it is large enough to admit of plenty of detail and not so large as to be cum-

bersome. Each square represents a square-set, while a dot at the line of intersection is used to indicate a post. With such a scale, the book, on being opened, will represent on a double page about 400 feet in length of the vein, and will be wide enough to permit of two floors being plotted on the same sheet one above the other. The sketch of the sill floor of each level is made in the field-book for the work of 'taking up stopes' underground. Where the drift timbering is regular, that is, where each side conforms to the standard drift set for the mine, the posts of a set are simply sketched in by a dot at each corner of the square; but where conditions are such that regular sets cannot be used, it is essential to indicate just where and how each irregularity occurs.

The data give correct representations of all chutes and manways that have been run on all floors, in such a manner that their true position with regard to the level and the stope can be known at a glance. The field stope-book thus compiled furnishes a permanent record of the work in the mine, shows the manner in which the development work was prosecuted, the date at which it was done, and supplies the data for office maps and estimates of the amount of ore extracted, cost of the extraction, and the possible ore reserve. (See descriptions and illustrations, p. 203.)

String Surveys

Instead of using a transit or pocket transit, the surveys of secondary openings are frequently made by stretching strings between points and then reading their course by ordinary compass, and dip by clinometer, or by use of the hanging compass.[1]

Instead of using a compass, the strings may be stretched in triangles [2] and the lengths of the sides measured so that the angles may be calculated. When carefully done, the accuracy of this method is great. The triangles must not, however, contain any angles approaching 180°, or the point of intersection of the two strings cannot be determined accurately.

[1] Longdale Iron Mine, *Engineering and Mining Journal*, August 1, 1891.

[2] *Trans. A. I. M. E.*, August, 1900; and *Eng. and Min. Jour.*, January 27, 1900.

Estimating Values of Ore Deposits

While a coal mine may be measured up, and an almost exact estimate of the number of tons of marketable coal which it will produce may be made, it is impossible to do the same in the case of a metal mine. Coal producers must always take into account, and make provision for, increase of wages, strikes, increased railroad charges, and varying prices of the coal produced. Besides all these, in metal mines, there is the uncertainty of continued richness and size of ore bodies with extended working.

Many attempts have been made to invent a formula which shall give the net profit per ton of ore handled. These are all impractical. Each mine or ore deposit is a case by itself. But in almost every case, the framework upon which the examining engineer hangs his observations, notes, assays, and geologic observations is a map of the mine survey.

The absolute necessity for an accurate map of the mine is, perhaps, only understood by the engineer who has been called to examine a large property, the mine maps of which have not been at hand.

Volumes

For estimating the volumes of open-cut work, placer digging, etc., various methods and formulas have been devised. S. Napier Bell[1] describes quick methods which he has used. By one he takes the profiles of cross-sections, making one transit setting in each section, and taking vertical angles to various points on the section, measuring by tape or by stadia. The mean area of two adjoining sections is multiplied by the distance between them to give the volume. This method is rapid and is accurate enough for many purposes.

By another method the topography of the surface is taken by level readings (or inclined side-shots) to points on the surface. Each three of these points are assumed to be the angles of a plane triangle. This triangle is called one end of a vertical triangular prism. The other end is any assumed horizontal plane. By calculating these vertical prisms over the whole area, the total contents of the excavation prism are known at any time. The

[1] *M. and M.*, vol. xxvii, p. 42.

difference between these totals at any two consecutive surveys is, of course, the cubic content of the material removed during the intervening time. This method is more accurate than the former one, but takes considerably more time.

Mine Sampling

While mine sampling is not a part of mine surveying, it so frequently is one of the additional duties of the mine surveyor that it seems best to at least outline the work.

The engineer has the assay maps of the mine to keep up to date, and usually marks the points from which systematic mine samples are to be taken, even if he does not oversee the work of breaking the samples, or even break them himself. The engineer who does not carefully study and map the geology, and also map the position of samples and resulting assay values, will usually have to step down and out. Of course, in large properties where mining geologists and special samplers are employed, the surveyor pays no attention to these things, but in all except the largest and most up-to-date properties, the surveyor must also be geologist, mine sampler, and frequently assayer as well.

Theoretically, the sampling of a mine is a very simple operation; representative fragments of the ore are broken from the different ore-bodies and assayed. The value per ton multiplied by the number of tons evidently gives the gross value of the ore in place. Assuming certain costs for mining and reduction, it is a simple matter to figure the net profit.

But practically the work is far from simple, owing to the difficulty of securing a truly representative sample of any particular body of ore. The ore-body may be exposed on one, two, three, or four sides and, of course, the greater the proportion of exposed area to the cubic content of the body, the more nearly representative of the whole mass will be the average of the samples; but at best, only an approximation, be it ever so close, can be secured by means of sampling ore in place in the mine.

Sample Interval. — The mine sampler must first decide upon some particular sample interval, i.e., distance between points at which samples are to be taken. This is different for each particular mine; a coal vein need be sampled only at distances of perhaps several hundred feet, while a narrow, rich, pockety gold vein must

be sampled at intervals of perhaps only 24 inches. Each ore deposit is a law unto itself, and in order to best determine upon the sample interval, the engineer will probably have to study the geology of the deposit, have a few selected (commonly known as 'grab') samples assayed, and perhaps begin his sampling at multiple intervals; i.e., instead of sampling at every 5 feet at first, he will sample at every 10 feet and later on sample at the alternate 5 points if the results from the assay of the 10-foot samples indicate the necessity of closer sampling.

Method of Breaking Samples. — The method of actually breaking the sample varies with the physical shape and condition of the material to be sampled. Whatever its shape or condition, a groove must be cut clear across the exposed face so as to secure a proportionate part of each band of material.

If the material be soft like clay, a scraper will cut the desired groove, and if brittle like coal, a small hand pick or prospector's hammer may be satisfactory; for harder materials a gad, or moil and hammer are best. For very hard material a moil struck by a heavy double-handled hammer may be necessary.

To catch the fragments as they are broken away from the face, the most satisfactory method is to have a second man hold up a candle or powder box so that all fragments will fly into it.

In case very large samples are to be broken, it may be better to use a canvas sheet spread on the floor of stope or drift. This method is, however, open to the objection that the sample is so easily salted, either intentionally, by having fragments of high grade thrown into it, or accidentally by having the richer, fine or brittle ore breaking from the back outside of the sample groove.

Size of Sample. — The size of a sample depends upon the width of the face sampled and the condition of the material. If the face be of uniform structure so that the dimensions of the groove can be kept uniform, a 5-inch by ¾-inch channel is probably large enough; but if the face be composed of alternating hard and soft bands, it may be necessary to increase the size of the channel to 10 or 12 inches by 3 inches in depth.

Reducing the Size of the Samples. — Where the samples are being taken for the mine and can be sent direct to the mine-assay office, the samples are, of course, reduced in the office. Where the samples have to be sent to some distance to be assayed, they must be reduced upon the ground. The small hand crusher is the

most convenient and can usually be secured, but frequently the rock must be crushed by other means. A heavy casting (old anvil, or stamp die) laid upon a sheet of canvas serves as a convenient base upon which the ore is crushed by means of a hammer. A band of iron with a handle is convenient for holding the pieces while breaking them.

After breaking to the required size, the canvas is rolled back and forth until the ore is fully mixed, the resulting pile of ore quartered or halved till of small bulk and then bucked down to say 100 mesh. Instead of bucking it down, the sample may be sealed in canvas or paper sacks and later bucked down at the assay office. The samples should be numbered by means of paper, wood, or metal tag inside the sack, and an identification (not the assay number) marked upon the outside of the sack. This last is a safeguard against intelligent salting; if an occasional sack of barren rock is included and it shows a metal content upon assay, one at once suspects salting and governs himself accordingly.

The sampler must be always upon his guard against salting; accidental, under all circumstances, and intentional, whenever there is anything for anyone to gain thereby. The tricks and schemes whereby salting is accomplished are very numerous. They vary all the way from throwing high-grade into the sample box as the sample is being broken, through the injection of gold chloride through the sample sacks, to the secreting of gold buttons in the sides of the crucibles which are used in assaying.

The work of the sampler is hard and tedious. It must be carefully and intelligently done. While the sampler can, and should, have a miner to do the actual pounding of the moil, he must be present constantly to see that nothing detrimental to the securing of a true sample is done.

Bibliography: Secondary Openings. — Stope Measurements, *Eng. and Min. Jour.*, January 27, 1900; Measure of Stopes, *Colo. Sci. Society*, December 3, 1894; Stope Measurements, *Proc. I. of Mine Surv.*, vol. ii; Cross Sections in Rock Cuts, *A. S. C. E.*, 1890, p. 386; Examination of Mineral Properties, *S. M. Q.*, vol. iii; Volumes, *Mines and Minerals*, vol. xxvii, p. 42; Small Drifts and Stopes, *ibid.*, vol. xxi, p. 344. Stope measurements *Jour. Chem. Met. & Min. Soc.*, S. Africa, May, 1909.

VI

RECORD OF THE SURVEY

Field Notes

It should be recognized that field notes are not taken for the purpose of helping the memory of the party making them. They should be complete, so that one entirely unacquainted with the workings surveyed can make a correct map from them. In fact, it is generally the case that the notes are worked up and mapped by office men who have never seen the workings.

Besides the actual record of courses, distances, angles, etc., there should be noted the position and dimensions of every object affecting the mine in any way. This covers stables, ventilation system, drainage, power lines, haulage, rolls, faults, thickness of deposit and kind of rocks.

If one surveyor is taking care of several mines, he should have a separate note-book for each mine. A careful and complete index will save time and trouble. The notes of the day should be looked over carefully each night to see that no apparent errors go uncorrected.

The notes should be taken with lead pencil, and many chief engineers never allow an erasure. If a mistake is made, a line should be drawn through the part in error and the note rewritten. Erasing and rewriting is a fruitful source of error. A moderately hard pencil should be used and the characters made small rather than large.

Above all things, do not be stingy with space in your note-book. Use plenty of room, be extravagant even, rather than crowd your work. And remember that a neat note-book is to be desired. Many a young engineer owes his advance to a nicely kept note-book, and many another has failed of advance because his note-book did not recommend him.

The notes of the survey should, of course, be headed by the name of the place in which the survey is made, together with the

date. Often, too, the names of those engaged in the work are given, as also the name of the instrument used.

There are many ways of keeping the notes themselves, each engineer adopting a form which impresses him as the best. The point to be kept in mind is to record everything, and to do it in such a way that any other engineer who examines the notes will understand them readily. The notes cannot be made too plain. (For note forms, see pp. 191, 201.)

The forms differ from the forms used in surface work principally in having columns for vertical angle and distance, and for height of point. Columns are usually ruled for the inserting of values, coördinates, etc., which have to be calculated. These columns are filled in at a later time by copying from the calculation-book or ledger.

Note-Books

The ordinary transit, or field-book is sold by every dealer in surveyors' supplies. The pattern of ruling differs a little with each maker, but any one may be used. The right-hand page is best ruled into small squares where sketching is to be done.

Some companies have note-books especially ruled for them, and the headings of the columns printed. This gives the book a neat appearance and is a convenience, no doubt, for a new man on the surveying corps; but after working with any particular set of notes for a time, a person never looks to see the headings of the columns. He knows what each one is.

As regards size, the larger book has the advantage, so long as it is small enough to slip into an ordinary pocket. On the other hand, if a small book will carry the number of columns required, and have each one wide enough to take its note without crowding, there is no advantage in having it larger. One must always avoid crowding his notes.

Each book should have blank pages enough left at the front for the complete indexing of all the notes in the book. Upon the outside should be the number of the book, the dates between which it has been used, and the mine at which it was used. When filled up and filed away, the number and mine name should be put upon the back edge so that when lying or standing among others it may be identified.

[1] The advantages of the loose-leaf system have been realized by

[1] Loose-leaf records—Lee Fraser, *Eng. & Min. Jour.*, 12-25-09.

mine surveyors, and many of the large mining companies are now using it. Indeed, it is to be questioned whether the matter has not come to be a fad and is being carried further than common sense and convenience permit. That it has its advantages, however, no one at all familiar with underground note-books will question. The loose leaves are usually double and punched to be held in covers much like the ordinary surveyors' field-book. L. C. Hodson [1] describes a system which is somewhat different. He says:

'I have tried the following plan which seems to eliminate all difficulties. Cards of the size of ordinary filing cards are ruled in columns for note-taking. Sheets of paper of the same size are ruled in the same way. These are placed in an envelope of oiled paper, the front of the envelope being printed with the same form as the card, and bearing the same serial number. For note-taking, the outside of the envelope is used, but copies are preserved on the card and sheet by means of carbon paper. The clean card is filed in a card-index cabinet and is not to be removed from the office, while the sheet is kept in a loose-leaf note-book, which can be carried whenever it is needed. By good indexing and use of different-colored cards for each class of surveys, all notes become instantly accessible at all times, no matter what note-book happens to be out of the office.'

SIDE NOTES [2]

Side notes are those notes of the survey which are needed in order to draw a correct map of the openings, but which are not necessary in order to correctly map the traverse lines of the survey. These include the pluses to all points to be noted, such as ore chutes, upraises, winzes, side openings to rooms, etc., and the distance to the sides of the opening at all points along the traverse line.

The methods of recording these notes are, of course, varied. There are several different ways, first, in which the notes are taken, and the method of keeping the side notes will, of course, depend upon the method of taking them. The different ways of taking may be roughly classified as: (1) The side notes of each sight follow the transit notes of that sight, and on the same page; (2) they

[1] *Iowa Engineer*, May, 1907, p. 131.
[2] System used in Bisbee, Ariz. *M. & M.*, Oct. 1909.

are entered in the same book on the opposite page; (3) the transit notes of the whole survey are followed by the side notes in the same book; (4) each set of notes has a separate book.

The means of record are then classified as follows: (1) Side-shots recorded and no sketch made; (2) a sketch made as nearly to scale and direction as is possible; (3) the red centre line of the right-hand page is used to represent the transit line; the lines to each side of it represent the walls of the opening, and the distances are written in between.

The method without sketches is to be condemned except for unusual openings, such as long tunnels without side openings. A sketch made to scale and direction is usually a failure as far as its being a true picture of the workings is concerned. It will frequently run off the page, and has little to recommend it. The last method is, then, the most satisfactory and is probably the one most used at present.

Sometimes the notes of the survey consist entirely of sketches (see p. 205).

When carrying the transit notes on the left-hand page and the sketch on the right-hand, it becomes convenient to use the railroad surveyor's trick of beginning to record one's notes at the bottom of the page and working up rather than *vice versa*. Where this is not done, the average noteman must turn his book around in order to keep his sketch running forward.

Office Books

When the field-notes are brought to the office, they are copied into the ledger, or office note-book. This must show not only the notes taken in the field but also the calculated quantities. The heading of each survey must show the date of the field work and by whom done, the date of entry and by whom the calculations were made, also the index numbers to show where the field-notes and the calculation work are to be found. On page 130 is illustrated a double page of the ledger.

Calculation-Book

All calculations are made in large books expressly for that purpose. The heading shows the date, date of survey, and

EXAMPLE OF LEDGER HEADING. DOUBLE PAGE

Page 273

Date..........

Calculations by..........

Notes. Field in Book..........Page..........Date..........

Calculations—Book..........Page..........

Page 273

Field work done by

Transitman..........

Assistant..........

Station	Angle R	Azim.	Bearing	Slope Dist.	Horiz. Dist.	Latitude			Departure			Vert. Ang.	Vert. Dist.		Height of Sta.	H. I.	H. of Point	REMARKS
						North	South	Total	East	West	Total		Plus	Minus				

reference pages of the ledger and field-book, also the names of the men doing the calculations. Some system must be adopted so that the exact part of the work wished may always be found in a particular part of the page. All work is, of course, done by means of logarithms and the calculation page shows a series of additions and subtractions.

The first calculation for any course is the reduction of the slope distance to horizontal and vertical distances. The calculations for this are as follows:

log slope dist.	=		=
log sin V. A.	=	log cos V. A.	=
log vertical dist.	=	log horiz. dist.	=
vertical dist.	=	horiz. dist.	=

The next to be calculated are the departure and latitude (or local coördinates of the point sighted) of the course. This appears as follows:

log horiz. dist.	=		=
log sin bearing A.	=	log cos bearing A.	=
log departure	=	log latitude	=
East (or West)	=	North (or South)	=

These local coördinates added (algebraically) to the total coördinates of the station of set-up, give the total coördinates of the station sighted.

To the elevation of the set-up station is added (again algebraically) the H. I., Vert. Dist., and H. P., to give the elevation of the station sighted. Where the point of origin of the coördinate system of the mine is at, or above, the surface, the vertical coordinate of the stations grows larger as depth is increased, and the signs of H. L., V. D., and H. P., are the opposite from what they are if the stations are carried as elevations (Figs. 24 and 25).

In making these calculations it saves time to have two men work together to check each other. If one man simply repeats his work for a check, he is very apt to make the same mistake the second time, and the error thus goes undetected.

The ledger and calculation-book are never taken from the office. Any notes required outside are copied into field-books. The mapping is done directly from the ledger.

After entering the notes in the ledger and making the calculations, the field-book is indexed to show to what pages in the ledger and calculation-book the notes have been transferred.

Text-Books. — Ihlsing's 'Manual of Mining'; Lock's 'Practical Gold Mining'; Underhill's 'Mineral Land Surveying'; 'Coal and Metal Miners' Pocketbook'; 'Theory and Practice of Surveying', Johnson; 'Principles and Practice of Surveying', Breed & Hosmer; 'Mine Surveying', Lupton; 'A Study of Mine Surveying', L. E. Young; Gillette's 'Earthwork and Its Cost'; 'Mine Surveying', Broughs; 'Ore and Stone Mining', Foster; 'Colliery Surveying', T. A. O'Donahue; 'Ore and Stone Mining', C. LeN. Foster.

VII

THE USES OF MINE MAPS

'A PLAN which requires the presence of the person or persons by whom it was prepared to explain it, or to supply information which ought to have been on the plan, has its utility diminished in proportion to the omissions.' 'The value of correct and complete plans does not, in many cases at least, appear to be properly appreciated. It is no uncommon thing to see men blindly blundering about in mines, working deposits of complicated structure, without even a plan of the workings to guide them, much less a plan showing all the facts relative to geological structure, which the manager should have constantly before him.' The working plans are most important; others are secondary and taken from them. 'In fact, without a detailed knowledge of structure, it is as impossible for a manager to direct, with technical success, the operations of a mine in complicated ground, as it is for a doctor whose knowledge of anatomy is defective, to properly carry out some complicated operation upon the human body.'[1]

Maps.—The importance of mine maps is not too well understood. In no way can money be better spent than in making good maps of a mining property of any size. The money so spent will be repaid many times over. A map showing all workings is of the greatest value, but in speaking of good maps we refer to maps showing much more. A mine map should be constructed on the same principle as a machine drawing, if the fullest benefit is to be derived from it. A machine drawing, of course, is so full and complete that any mechanic can construct that machine without any explanation, or knowledge of its use, or without ever having seen a similar machine. In order that a machine drawing should be as complete as this, one drawing is insufficient, even in plan and section. Detail drawings must be provided. The same principles must be applied to mine drawings or maps. It may be stated without any hesitation or fear of contradiction that a mine map

[1] *Mining Reporter*, vol. xlviii, p. 165.

should be a pictorial representation of the details of work done in a mine, not merely the drifts, shafts, winzes, upraises, and stopes.

Anyone who has had occasion to look up old maps will know how exceedingly small is the practical information to be derived from them. Even the date of the map may not be shown. Now a mine map should show: (1) The extent and contour of the working; (2) the shape and extent of the ore shoots, and the nature of the ore found in them; (3) the geological features, such as variations in the wall rocks, faults, etc. A complete mine map must consist of several maps. These will be the main office maps, showing the workings pure and simple; the superintendent's working maps, on a scale sufficient for him to take them underground; assay maps, upon which are recorded the assays of all mine samples, thus showing the value and trend of all ore shoots; the geological maps, upon which are recorded the formations and their changes, the nature and details of faults, and any other geological facts deemed worthy of notice. Ask any superintendent or manager who is using such maps as to his opinion of their value, and not one would give other than a most emphatic testimonial as to the great importance of such maps to him in his daily work.

Now, many may demur to the practical value of such maps as being so expensive to maintain, and all recognize that to be of value they must be up to date. The answer is of course obvious. If by spending a dollar two are saved, then the dollar investment is a wise one. Practical examples are better than academic reasoning. Let us give two — Pennsylvania and Great Britain. Both, a number of years ago, required all mines to keep their maps up to within a month. Mine owners vigorously protested. It was found, however, after a few years' trial that in the coal and iron mines the maps showed enormous losses of mineral. The maps not only showed where the losses occurred, but how they occurred. The remedies were therefore suggested by the maps themselves. The advantages were so great that the scope of the maps is frequently extended beyond the requirements of the law. If those laws were repealed to-morrow, the maps would continue to be made.

Mining engineers know and appreciate the value of accurate mine surveys and maps, and most mines have maps which will answer all practical purposes, but there are mines without them. A full set of maps must embrace level maps, and vertical longitudi-

nal and vertical cross-sections of veins which have any considerable dip (see Figs. 60 to 73).

It is the practice to plot a general plan of the 'underlay' on a single sheet, showing each level in the mine, with all its details of development, winzes, raises, cross-cuts, and stopes, each being indicated by characteristic marking. The idea of projecting plan and vertical section on a single plane, as attempted occasionally, is unsatisfactory, and is never done by those familiar with the principles of mine mapping. The scheme of mapping each level separately, each level map drawn to a certain datum, is an excellent one, and tracings of these several level maps may be made, which admits of binding them together permanently or temporarily. The lines showing the several levels may then be examined simultaneously by placing the sheets one above another, and the relative position of the workings on adjacent levels studied.

[1] By plotting all the development work, and also the structural geological features (such as changes in character of rocks through which the workings pass, the dip of the formation, all dikes intersecting the workings, cross-veins, seams, faults, and gouges, together with their strike and dip), the maps may be made to serve their greatest usefulness. The breaks in the vein, which occur on any particular level, may be referred to levels above and below, as may any other geological irregularities which may occur. The lack of just this sort of knowledge has sometimes resulted in closing mines subsequently proved to be valuable.

Never, perhaps, is an accurate mine map appreciated so greatly as upon the reopening of a long abandoned property. Such mines are usually flooded, and when new work is undertaken, as connecting with works of an adjoining property, or sinking a new shaft to be connected with the old workings, the element of danger which attends such operations, owing to large volumes of water in the old works, is reduced to a minimum. The manager knows how far he is from the old levels or stopes, and can anticipate imminent danger and provide against it.

Accurate maps are also of great service in searching for new ore shoots, as by their use a comprehensive idea of the entire vein may be obtained, for a glance at the map places the development of several thousand feet, possibly, immediately under the eye, and the relations of the various portions of the mine become apparent.

[1] Survey in Practical Geology. *Bul. A. J. M. E.*, Aug., 1909.

Laws Affecting Mine Surveys [1]

Pennsylvania. — The requirements of the law with reference to mine maps vary somewhat in the different States, but those in the anthracite region of Pennsylvania are probably as rigid as anywhere, and are therefore given.

'Sec. 1. The owner, operator, or superintendent of every coal mine or colliery shall make, or cause to be made, an accurate map or plan of the workings or excavations of such coal mine or colliery on a scale of 100 feet to the inch, which map or plan shall exhibit the workings or excavations in each and every seam of coal, and, the tunnels and passages connecting with such workings or excavations. It shall state in degrees the general inclination of the strata with any material deflection therein in said workings or excavations, and shall also state the tidal elevations of the bottom of each and every shaft, slope, tunnel, and gangway, and of any other point in the mine or on the surface, where such elevation shall be deemed necessary by the inspector. The map or plan shall show the number of the last survey station and date of each survey on the gangways or the most advanced workings. It shall, also, accurately show the boundary lines of the lands of the said coal mine or colliery, and the proximity of the workings thereto, and in case any mine contains water dammed up in any part thereof, it shall be the duty of the owner, operator, or superintendent to cause the true location of the said dam to be accurately marked on said map or plan, together with the tidal elevation, inclination of strata, and area of said workings containing water; and whenever any workings or excavations are approaching the workings, where such dam or water is contained, or situated, the owner, operator, or superintendent shall notify the inspector of the same without delay. A true copy of which map or plan the said owner, operator, or superintendent shall deposit with the inspector of mines for the district in which the said coal mine or colliery is situated, showing the workings of each seam, if so desired by the inspector, on a separate sheet of tracing muslin. One copy of the said map or plan shall be kept at the colliery.

'Sec. 2. The said owner, operator, or superintendent shall as often as once in every six months, place or cause to be placed, on

[1] From 'Examination Questions', p. 30, International Text-book Co.

the said inspector's map or plan of said coal mine or colliery, the plan of the extensions made in such coal mine or colliery during the preceding 6 months. The said extensions shall be placed on the inspector's map, and the map returned to the inspector within 2 months from the date of the last survey.

'Sec. 3. When any coal mine or colliery is worked out, preparatory to being abandoned, or when any lift thereof is about to be abandoned, the owner, operator, or superintendent of such coal mine of colliery shall have the maps or plans thereof extended to include all excavations as far as practicable; and such portions thereof as have been worked to the boundary lines of adjoining properties, or any part or parts of the workings of which it is intended to be allowed to fill with water, must be surveyed in duplicate, and such surveys must practically agree, and certified copies be filed with the inspector of the district in which the mines are situated.

'Sec. 4. Whenever the owner, operator, or superintendent of any coal mine or colliery shall neglect or refuse, or from any cause not satisfactory to the inspector, shall fail for a period of 3 months to furnish to the inspector the map or plan of said colliery, or of the extensions thereto, as provided for in this act, the inspector is hereby authorized to cause an accurate map or plan of such coal mine or colliery to be made at the expense of the owner thereof, which cost shall be recoverable from said owner as other debts are by law recoverable.

'Sec. 5. If the inspector finds, or has reason to believe, that any map or plan of any coal mine or colliery, furnished under the provisions of this act, is materially inaccurate, it shall be his duty to make application to the Court of Common Pleas of the county in which such colliery is situated, for an order to have an accurate map or plan of said colliery prepared, and if such survey shall prove that the map furnished was materially inaccurate or imperfect, such owner, operator, or superintendent shall be liable for the expense incurred in making the same.

'Sec. 6. If it shall be found that the map or plan furnished by the owner, operator, or superintendent was not materially inaccurate or imperfect, the Commonwealth shall be held liable for the expense incurred in making said test survey.

'Sec. 7. If it shall be shown that the said owner, operator, or superintendent has knowingly or designedly caused or allowed

such map or plan when furnished to be incorrect or false, such owner, operator, or superintendent thus offending shall be guilty of a misdemeanor, and upon conviction thereof shall be punished by a fine not exceeding $500, or imprisonment not exceeding 3 months, at the discretion of the court.

'Sec. 8. The maps or plans of the several coal mines or collieries in each district, and which are placed in the custody of the inspector, shall be the property of the Commonwealth, and shall remain in the care of the inspector of the district in which the said collieries are situated, to be transferred by him to his successor in office, and in no case shall a copy of the same be made without the consent of the owner, operator, or superintendent.

'Sec. 9. The inspector's map or plan of any particular colliery shall be open for inspection in the presence of the inspector to any miner or miners of that colliery whenever said miner or miners shall have cause to fear that his or their working-place or places are becoming dangerous by reason of its proximity to other workings which may be supposed to contain water or dangerous gases. Said map shall also be open to the inspection and examination of any citizen interested, during business hours.

'Sec. 10. It shall be obligatory on the owners of adjoining coal properties to leave, or cause to be left, a pillar of coal in each seam or vein of coal, worked by them along the line of adjoining property, of such width that, taken in connection with the pillar to be left by the adjoining property owner, will be a sufficient barrier for the safety of the employees of either mine in case the other should be abandoned and allowed to fill with water; such width of pillar to be determined by the engineers of the adjoining property owners, together with the inspector of the district in which the mine is situated, and the surveys of the face of the workings along such pillar shall be made in duplicate and must practically agree. A copy of such duplicate surveys, certified to, must be filed with the owners of the adjoining properties and with the inspector of the district in which the mine or property is situated.'

In some States the ventilating currents must be shown on the map by arrows, and doors, brattices, overcasts, undercasts, etc., indicated.

Illinois. — The law provides, Section 1, that a map shall be made of every mine, upon a scale, not smaller than 200 feet to the inch, showing the surface-boundary line of the coal rights; and all

section or quarter-section lines or corners within the same; the lines of town lots and streets; tracks and side-tracks of all railroads; also wagon roads, rivers, streams, ponds, buildings, and other landmarks on the surface. The meridian and the scale must be given, and the engineer or surveyor must certify upon the map as to the date and accuracy of the survey. The map shall be marked with the name of the mine, the company or owner, and the State, county, and township where located. The map of the underground workings must show all shafts, slopes, tunnels, or other openings, all excavations, entries, rooms, and cross-cuts; the location of the fan or furnace, and the direction of the air-currents, location of pumps, hauling engines, engine planes, abandoned works, standing water, and the boundary line of any outcropping seam. A separate map must be made for each separate seam worked. The surface and underground maps must be drawn upon separate sheets, the surface map being drawn upon tracing linen so that it can be superimposed upon the underground plan, to show the relative position of the buildings and surface lines and the underground workings. Each map must show the rise and dip of the seam, from the bottom of the shaft to the fact of the workings.

The law provides, Section 3, for the making and maintaining of a second opening or escapement shaft, in every mine, in addition to the hoisting shaft or slope or drift, and allows three months for the building of such opening or escapement for shafts 200 feet or less in depth; six months for shafts more than 200 feet and less than 500 feet deep; and nine months for all other mines, slopes, drifts, or connections with adjacent mines. In all cases, the allotted time dates from the commencement of hoisting coal in the main shaft. The law makes unlawful the employment of more than ten men in any mine previous to the completing of such second opening or escapement shaft. The distance between the hoisting shaft and the escapement shall not be less than 300 feet, except with the agreement and consent of the mine inspector of the district, and no inflammable structure or powder magazine shall be erected between these two shafts.

The operator of a mine about to be abandoned shall cause a final survey of the mine to be made, and the mine maps extended so as to show all excavations, and the advance face of the workings in their exact relation to the boundary or section lines on the surface.

England. — 'In this country [England] there is absolutely no Government test for competency in a mine surveyor, and while this is the case, it can hardly be hoped that our practice can ever equal that abroad, except at a few mines under enlightened ownership or management. It is true that questions on surveying are included in the examination papers set for the manager's certificate, and it has been wisely ordained that a candidate must show some practical acquaintance with the subject ere he obtains his certificate; but the questions set are, in the main, of such an elementary character that an ability to answer them cannot by any means be taken as the sign of an efficient surveyor. In only two districts, to the writer's knowledge, is a slight intimacy with theodolite work required in certificate candidates, and in all other cases the questions are entirely on dials or dialing, or of the nature of "problems" needing very little, if any, knowledge of surveying in their solution, whilst it is only very occasionally that a question on leveling is seen.

'In Germany, the would-be mine surveyor has to pass a stiff examination, held by the Government, before being allowed to enter practice; and when in practice, his surveys are checked periodically by Government inspectors who resurvey a portion of the mine for that purpose. In Austria an accuracy of 1 in 5000 is required for theodolite work, and 1 in 20,000 for leveling. It would be interesting to know how many English colliery plans show an accuracy of more than 1 in 250.'[1]

Uses of the Topographical Map[2]

'(1) The relations of the mineral deposits to the property lines can be seen, and steps taken, if necessary, to secure or control adjoining properties before the work of exploration and development is begun.

'(2) The relation of the different outcrops and developments, and whether they represent one deposit or several, can be determined, sometimes at a glance.

'(3) The area of the portion of the property underlaid by the deposit can be measured, and the available areas of mineral at certain depths and within certain boundaries determined.

[1] Henry Briggs, in *Colliery Guardian*, July 6, 1906.

[2] H. S. Munroe's 'Examination of Mineral Properties.'

'(4) If the geological structure be complicated, all the known data can be brought together on the map and sections, and advantageously studied.

'(5) The probable outcrop line can be determined and traced on the map as a guide to works of exploration and development.

'(6) If necessary, the underground contours of the deposit can be determined approximately; and the probable depth of a shaft, or the length of a tunnel, to reach the deposit can be measured on the map.

'(7) Roads, buildings, and all surface work, and in general all works of exploration and development, can be better located and planned with the aid of an accurate map than is possible without such assistance.'

D. W. Brunton, of Denver, presented a paper before the A. I. M. E. at its British Columbia meeting in July, 1905, which presents in a splendid manner the way in which geological data should be collected and preserved in the form of mine maps and sections. Through the kindness of Mr. Brunton, this paper is reprinted in full. It was printed first in the *Bi-Monthly Bulletin*, No. 5, September, 1905, and afterward in Vol. XXXVI, of the *Transactions of the A. I. M. E.*

Geological Mine Maps and Sections

'The maps of our large mines are usually prepared with the greatest care; and it is somewhat singular that, in comparison with the great amount of time and money spent in surveying and platting, so little actual use is made of them. Almost the only purpose for which a completed survey map is afterward consulted is the determination of the relative position of the different workings to each other, and to the boundary lines of the property.

'After the completion of such a map, it should be made the beginning of another, and in most cases a far more important undertaking, namely, its utilization as a starting-point for a complete inventory of the company's underground possessions. The ordinary mine-survey map, being nothing but a record of what has to be done, is, in one sense, only ancient history. To increase its

value, such additions should be made as will render it a complete statement of the amount and value of ore in sight at any particular time, and a guide for future developments. Comparatively little extra labor is involved in this undertaking, since the larger and most expensive part of the work has already been completed when the mine has been surveyed and mapped. The necessary additions consist in working out, and platting on the maps, the geology of the mine as exposed in the workings in such a manner that the geological survey may be of a daily use in the development and operation of the mine.

'The first step toward the production of a geological map consists in tracing individual level-sheets from the general or composite map. The area to be included, outside of the property in question, will depend very much on local conditions; but for geological, legal, and commercial reasons, it should be extended as far as reasonably practicable. The scale to be adopted likewise depends on local conditions and individual preference, but experience has shown 40 feet to the inch to be a very convenient scale. Where the area to be included would necessitate a map of more than 30 inches wide by 36 inches long, it is better to divide it into different sections, the maps of which can then often be made somewhat smaller, say, 24 by 30 inches, which is a very convenient size.

'The individual level-sheets should be very carefully made, so as to register perfectly, and should be perforated (preferably on the left-hand side) to pass over three pairs of arch-files, secured to the left-hand side of a very thin paneled frame about 1 inch larger all round than the maps, somewhat after the manner of an arch-file bill-holder. The vertical stems on the front of the files hold the individual level-sheets in position so that they register perfectly with each other, and the swinging hooks at the top permit the removal of any sheet for additions or corrections.

'To keep the sheets from curling, a heavy paste-board cover should be fitted over the top; and, instead of perforating it for the front uprights, it will be found better to cut longitudinal slots to take both front and back uprights, so that the cover can be readily lifted off whenever the sheets are to be used.

'Where a district of considerable area has to be covered and a large number of section-books are required, they are most conveniently kept in a horizontal position in a case provided with

runners, the same as drawers, and, in order to economize space, special arches 1.5 inches lower than the regular pattern can be readily obtained from the factory.

'After the individual sheet-maps are traced, the next step is to transfer them by means of carbon paper into pocket note-books. Any size may be adopted for this work; but in practice it is found that a large book (say 8 × 10 inches), permitting comparisons over a considerable area, is most convenient. In some cases, where the geology is reasonably simple, a convenient plan is to take very light colored blue-prints of the individual level-sheets directly into the mine. These can be folded up into a convenient size for carrying in the pocket, and unless the geology is extraordinarily complicated will answer every purpose. In taking the geology of different levels the greatest care must be taken to record the facts exactly as they occur in the ground, without bias for or against any previously adopted theory. In old workings the openings must be examined with the greatest care, in order to determine exactly the boundaries of the ore-body, and the strike and dip of the spurs and intersecting veins, as well as of all faults, slips, water-courses, etc.

'After the geological records have been thus brought up to date, the geology of new workings is very much more easily determined. In fact, it will usually be found that the foremen, shaft-bosses, and even the common miners, will take such an interest in the work that every change of rock or ore-values, and every slip or fault, will be pointed out to the geologist by the men, instead of his having to hunt for them, as he has had to do in the older workings.

'It has alway been found that, when the work is recorded in exact accordance with observed facts, the theories will take care of themselves, and little or no difficulty will be experienced in interpreting the facts when vertical sections are made from the horizontal sheets. These are to be platted directly from the horizontal level-sheets, and, if the work has been carefully and correctly done, the result will be a set of vertical geological sections of the greatest value, not only in checking up the work on the horizontal sections, but also in furnishing the best possible basis for measuring the rate of development and ore-extraction, as well as determining at any time the amount and value of ore in sight.

'Both horizontal and vertical sections may be used for the

recording of samples, the better plan being to encumber the map only with the number of the sample; the description of the ore, the width samples, etc., together with the assays, being entered in a separate note-book.

'The entire system will be readily understood upon a study of the accompanying illustrations, which, as engraved, differ from the originals in three respects: (1) They have been reduced in scale; (2) they are bound in place, so that the several sheets are not removable, as they would be in practice; and (3) the colors which are most convenient and effective in practice are here replaced with conventional *hachure* in black.

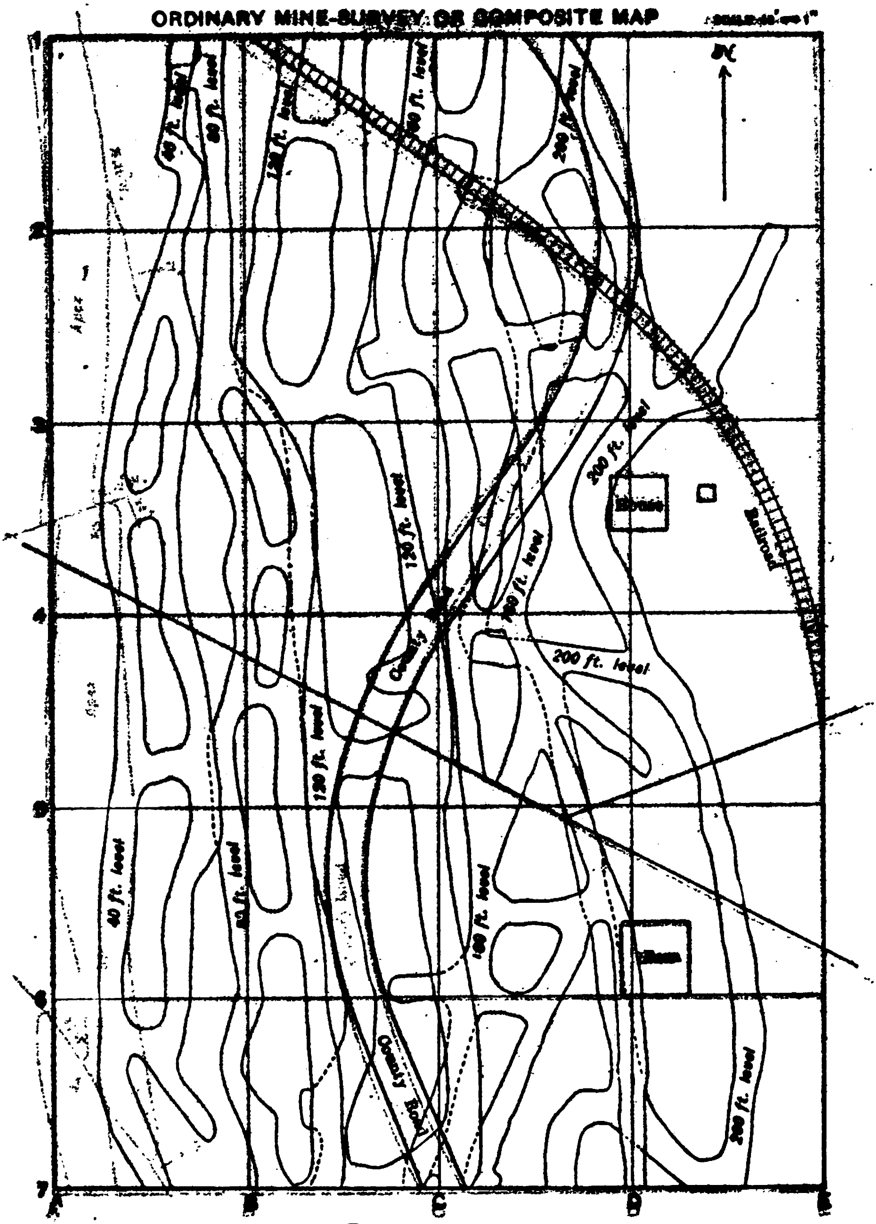
'I would here say that, in my judgment, every company operating large mines would find it advantageous to employ, as a separate official, a competent mining-geologist, whose duty it should be to follow continuously all workings and surveys, and note with precision those indications which hard-worked superintendents, foremen, and surveyors, however intelligent, might easily overlook or fail to record. The proper man for this most important work is a man who has nothing else to do, and who will do this one thing with industry, enthusiasm, and technical knowledge.

'*Description and Discussion of Illustrative Drawings.* — These drawings represent an imaginary mine, presenting the ordinary conditions of practice.

'Fig. 60 shows an ordinary mine map, sometimes known as a composite map. This is useful only for showing the relations of the workings to each other and to the boundary lines of the property. It does not form a record of the ore-bodies encountered, or the disturbances to which they may have been subjected, nor has it any great value as a guide in further developments.

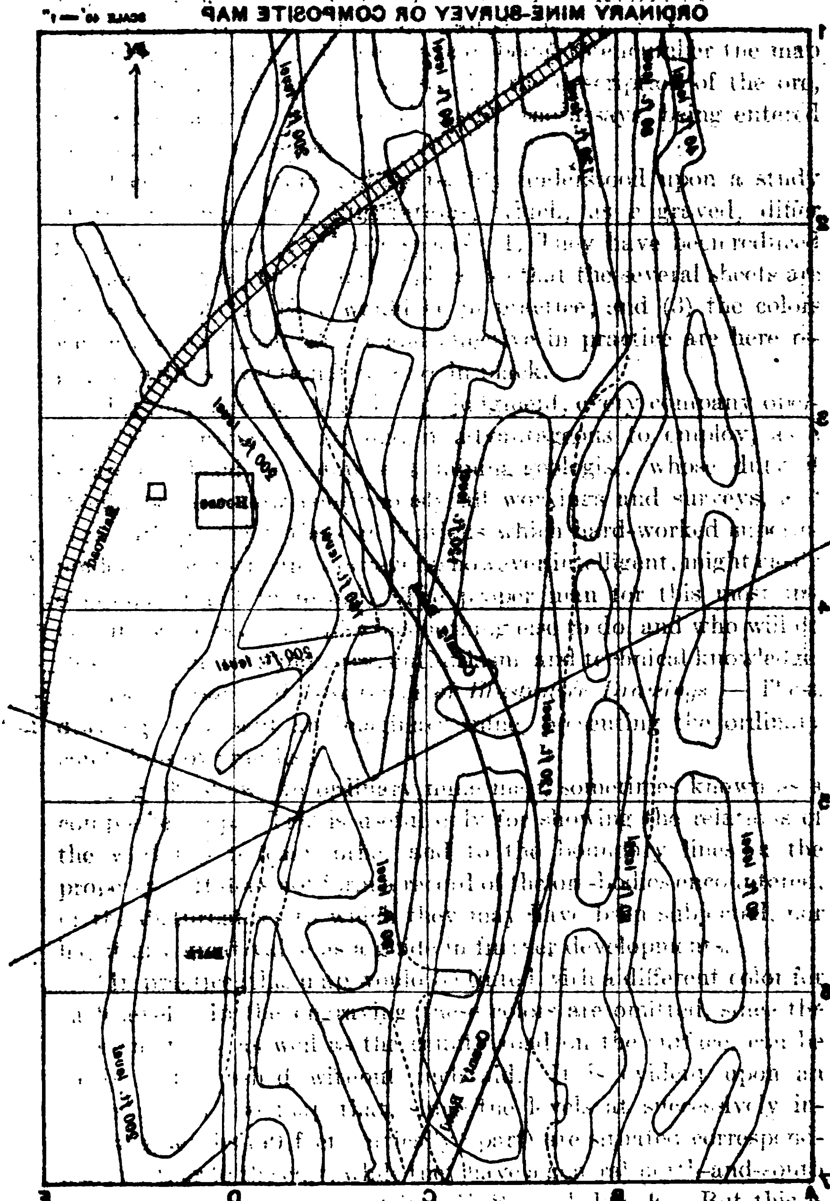
'In practice, this map would be tinted with a different color for each level. In the engraving these colors are omitted, since the different tints, as well as the county road on the surface, can be easily distinguished without such aid. It is evident upon an inspection of the map that, since the levels at successively increasing depths (40 feet vertically apart) are situated correspondingly farther to the east, while they have a general north-and-south direction, the ore deposit strikes N.-S., and dips E. But this is all that the map can tell us concerning it.

'Figs. 62–66, are the individual level-sheet geological maps. Each of these level-sheets is traced directly from the ordinary



From the Transactions of the A. I. M. E.,
vol. xxxvi, pp. 508–540.

FIG. 60.



From the Transactions of the A. I. M. E.,
vol. xxxvi, pp. 508–540.

FIG. 60.

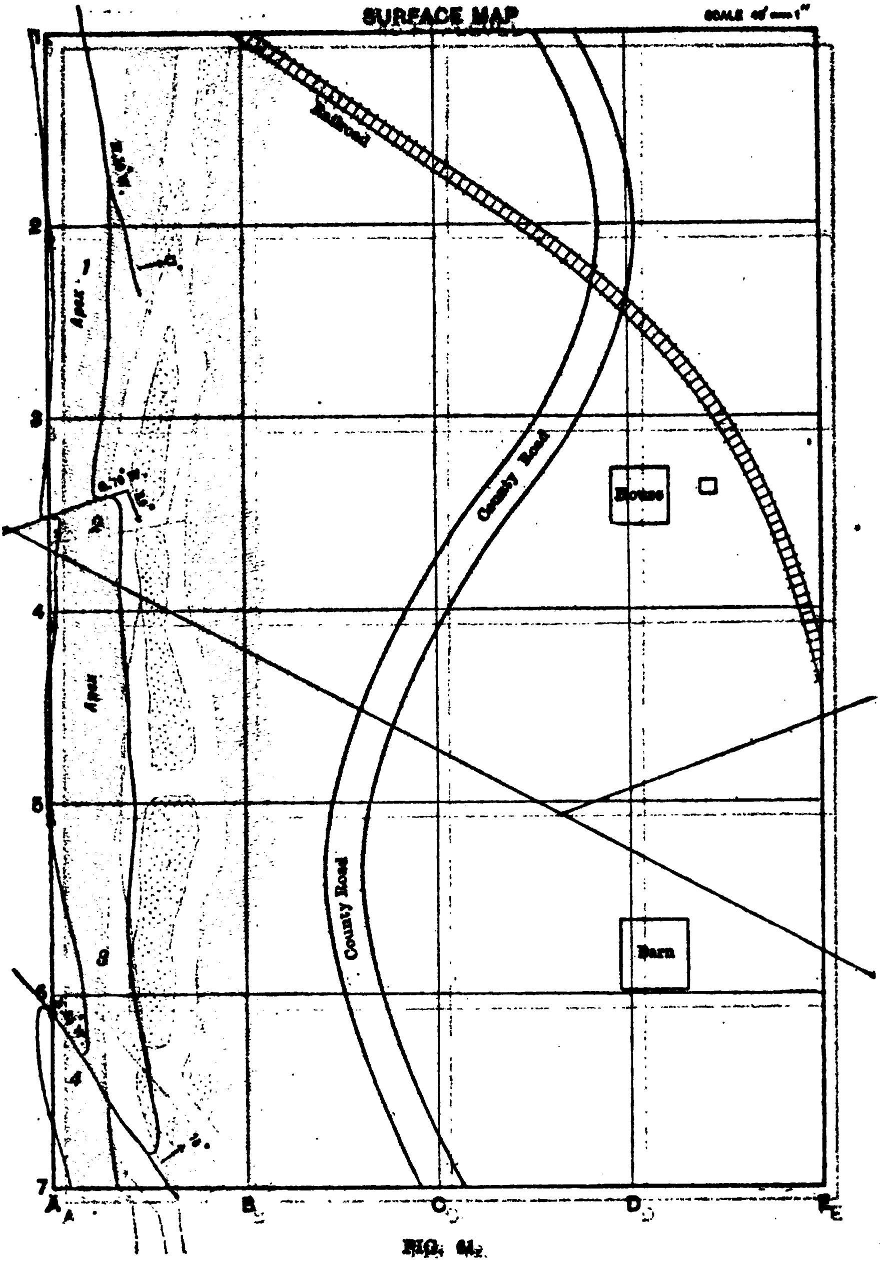


FIG. 61.

LEGEND

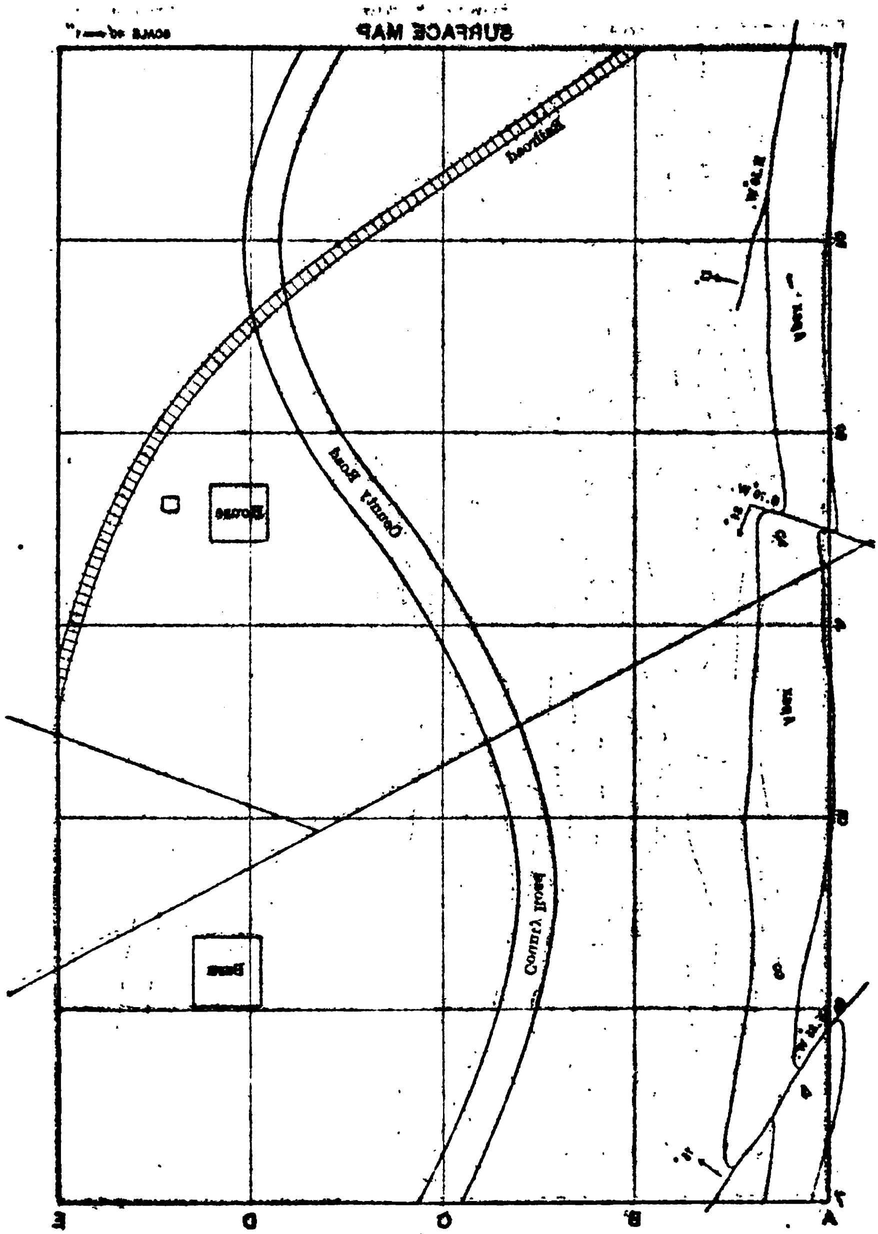

SURFACE MAP
Railroad
County Road
County Road
House
Barn
A
B
C
D
E

FIG. 61.

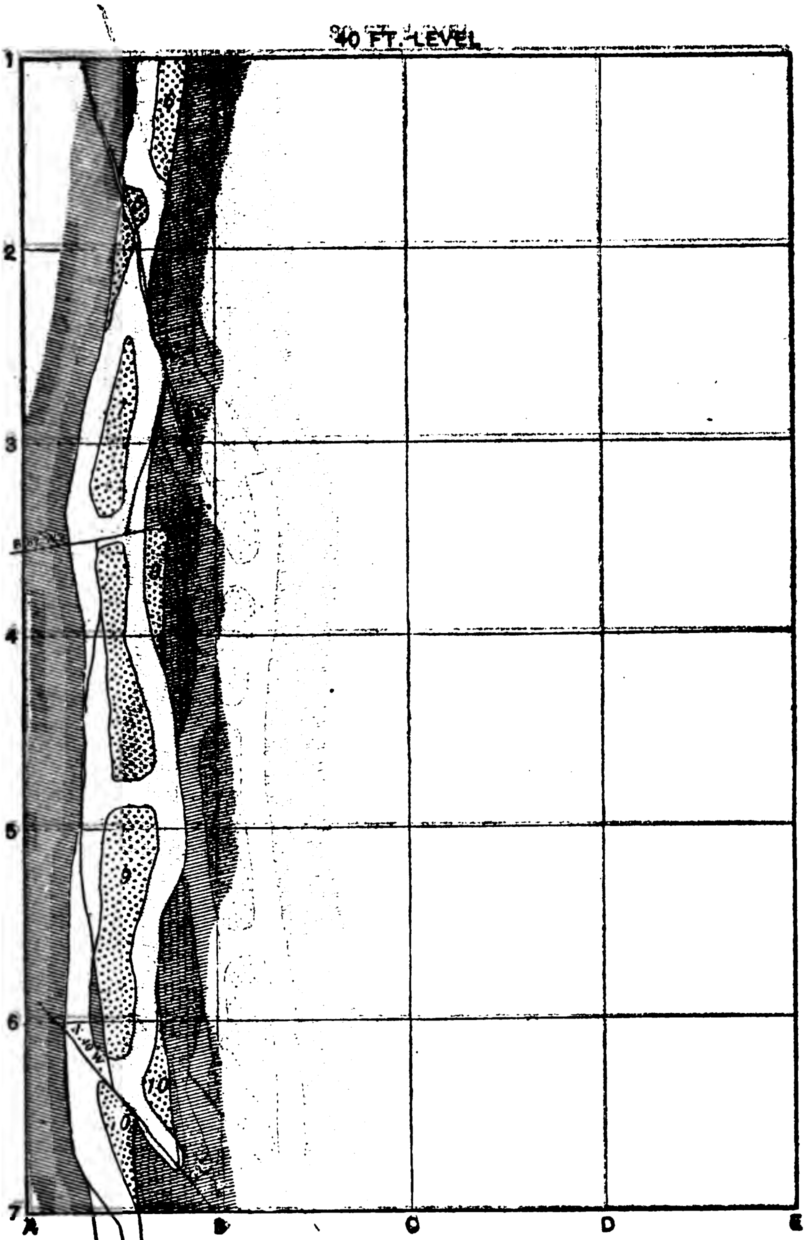


FIG. 32.

40 FT. LEVEL

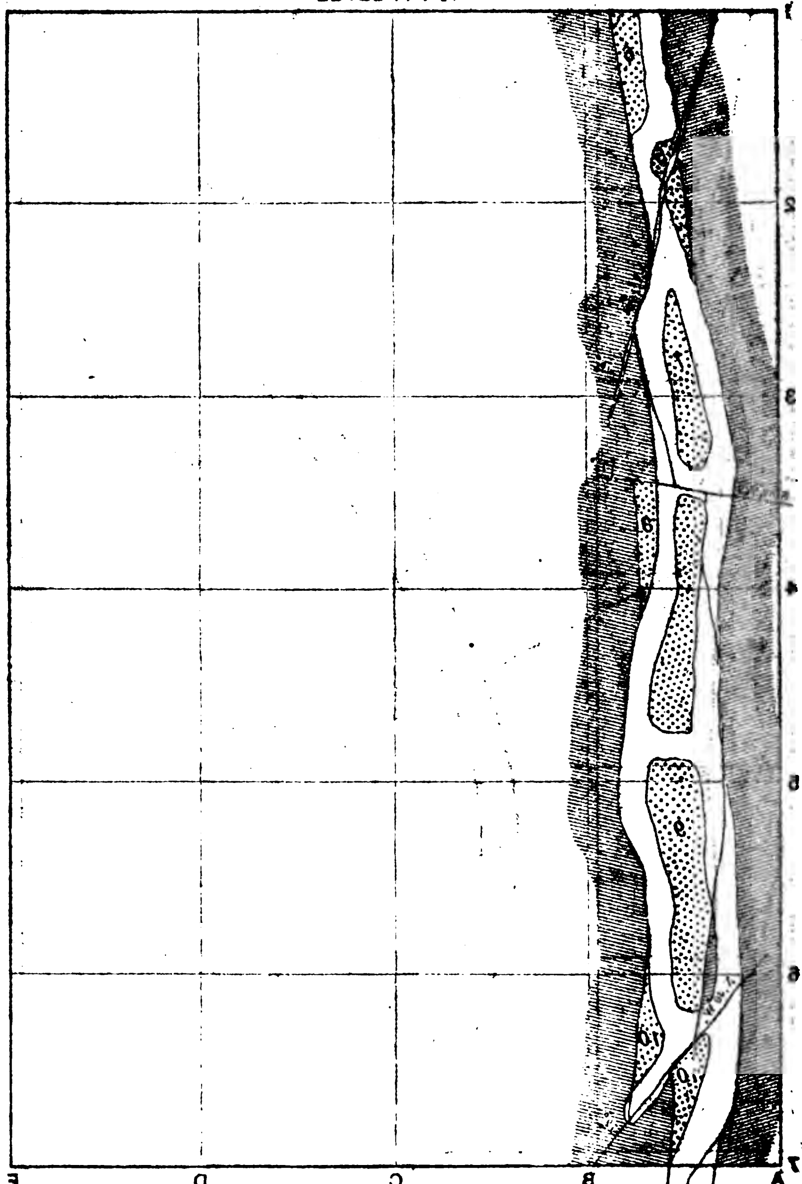
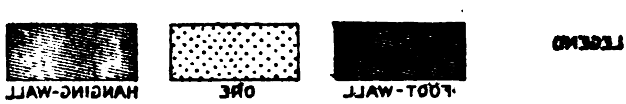


FIG. 62.



[illegible] FT. LEVEL

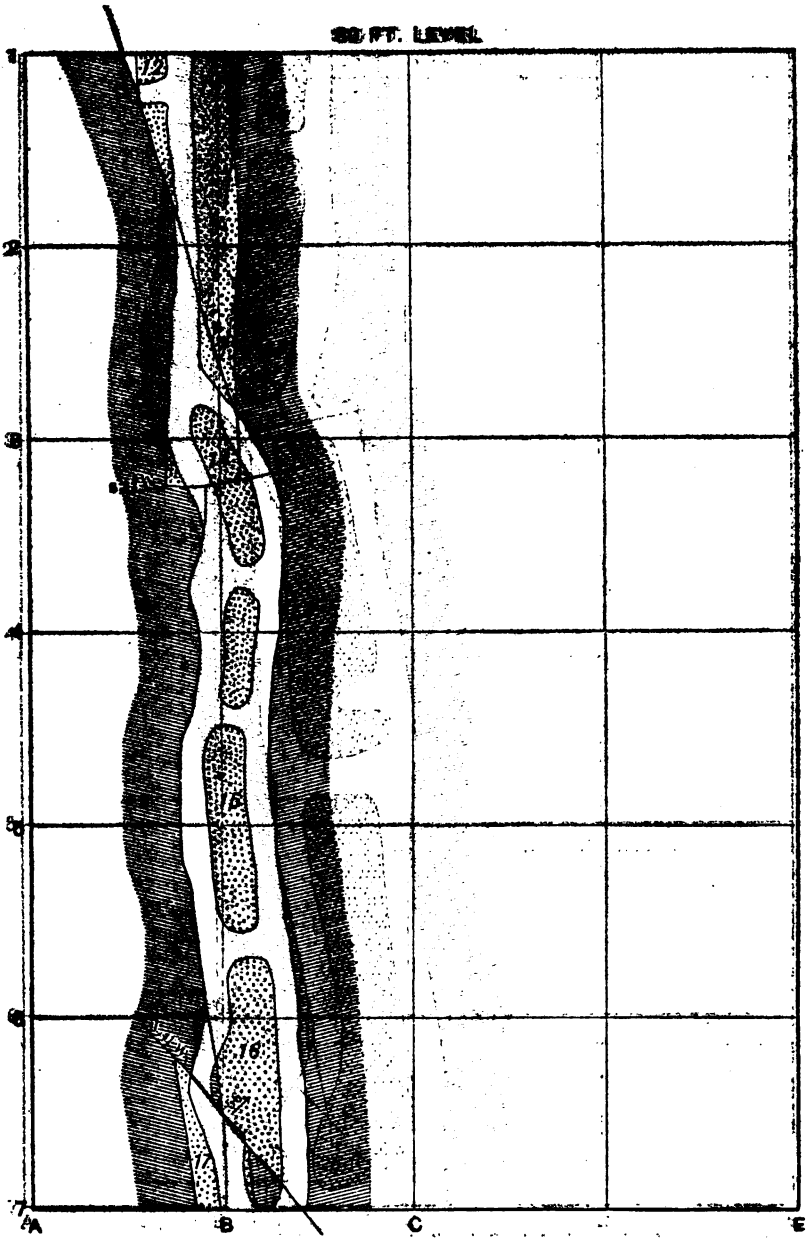


FIG. [illegible].

80 FT. LEVEL

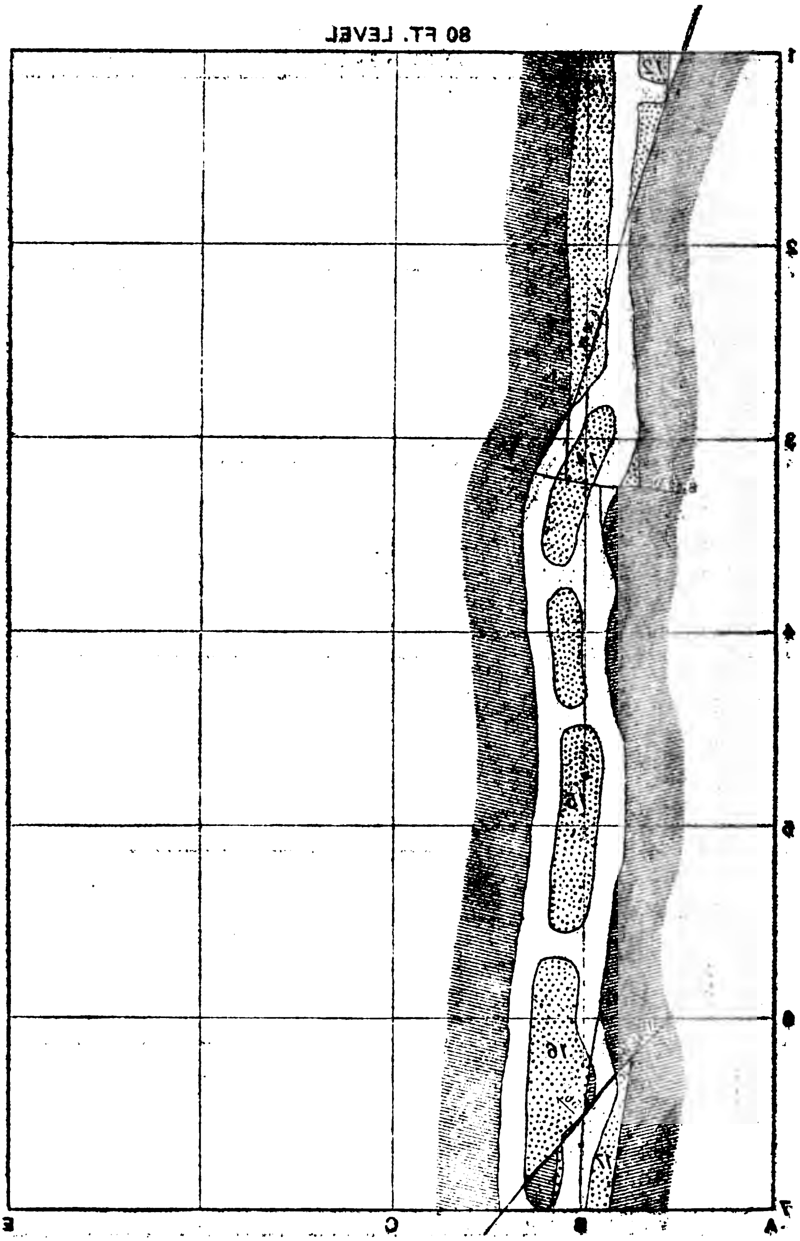


FIG. 68.

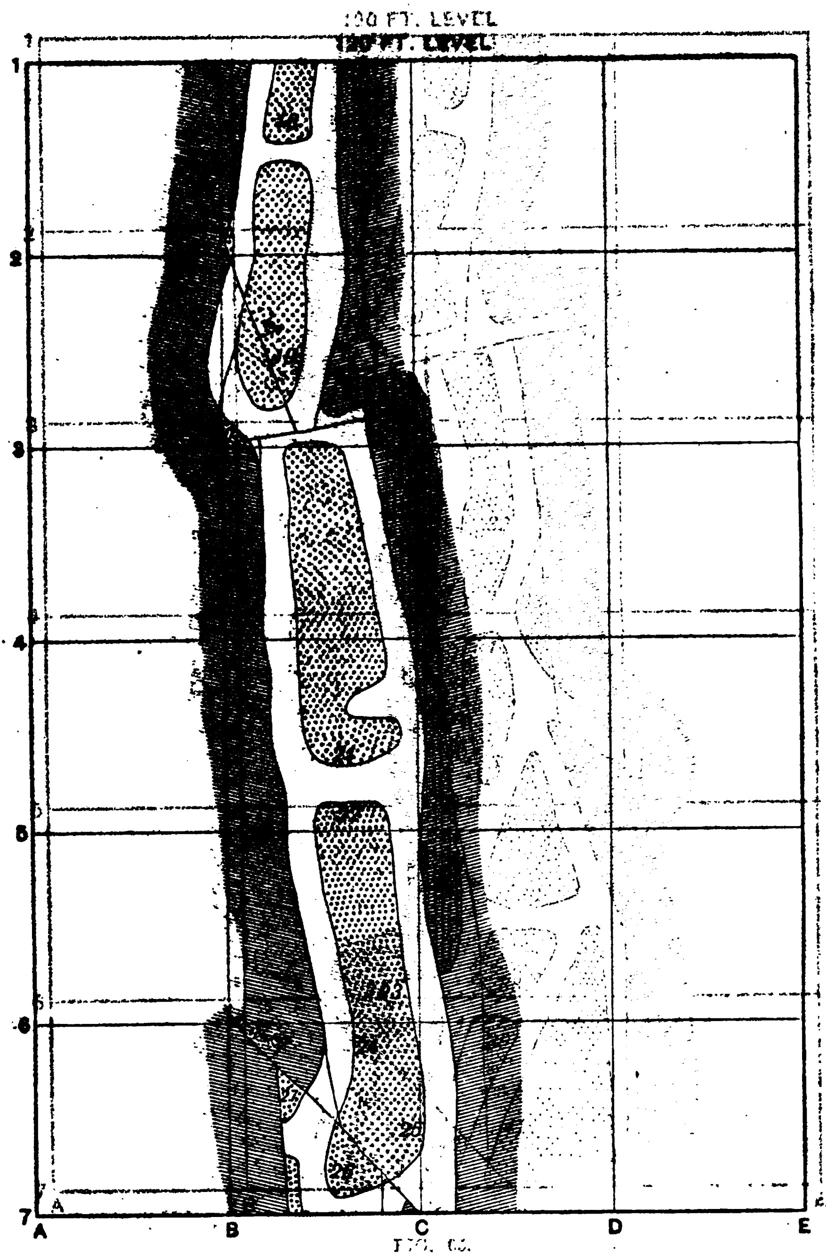


FIG. 64.

FIG. 94.

380 FT. LEVEL

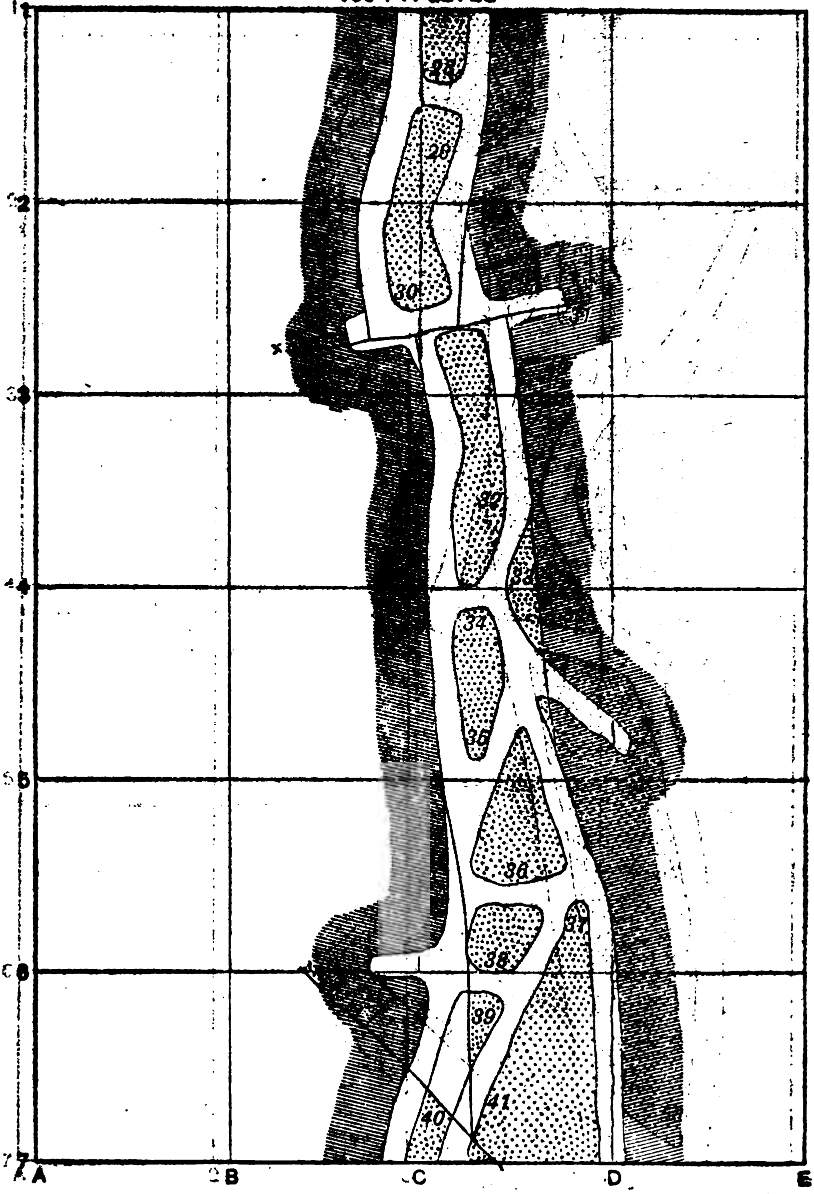


FIG. 65.

160 FT. LEVEL

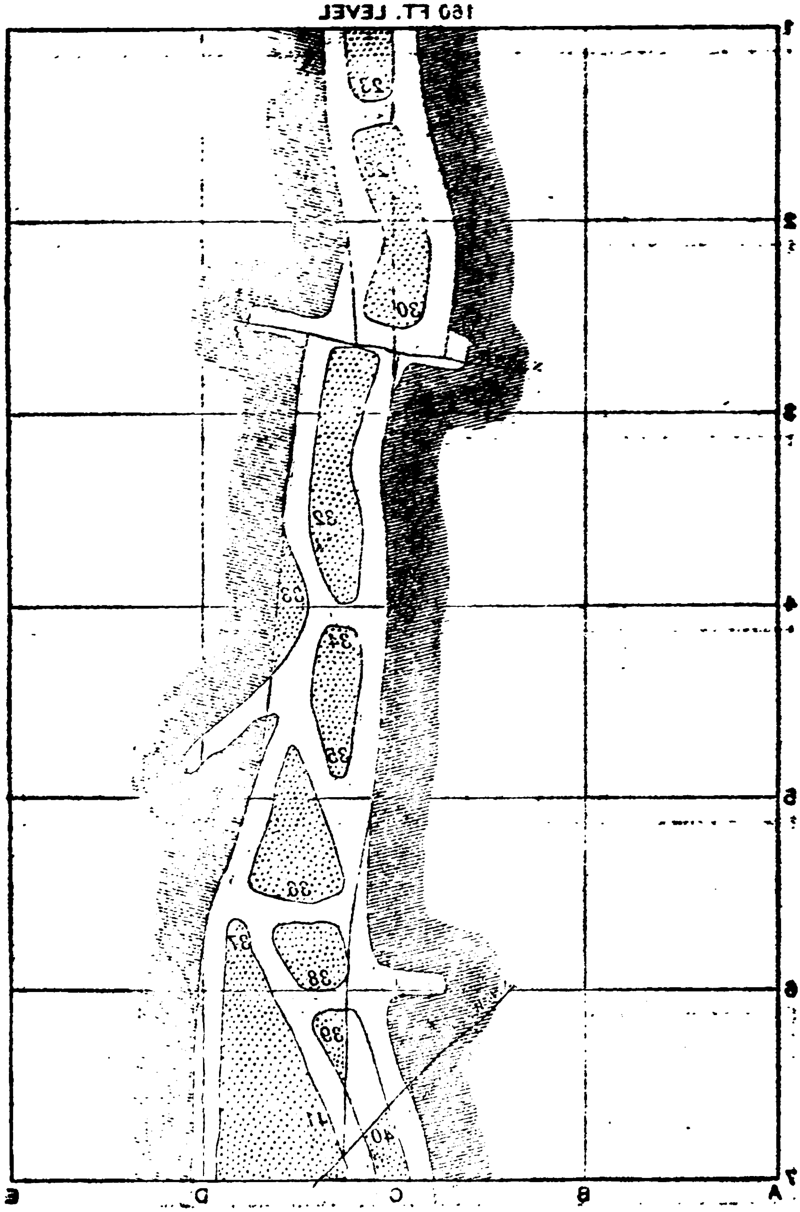


FIG. 63.

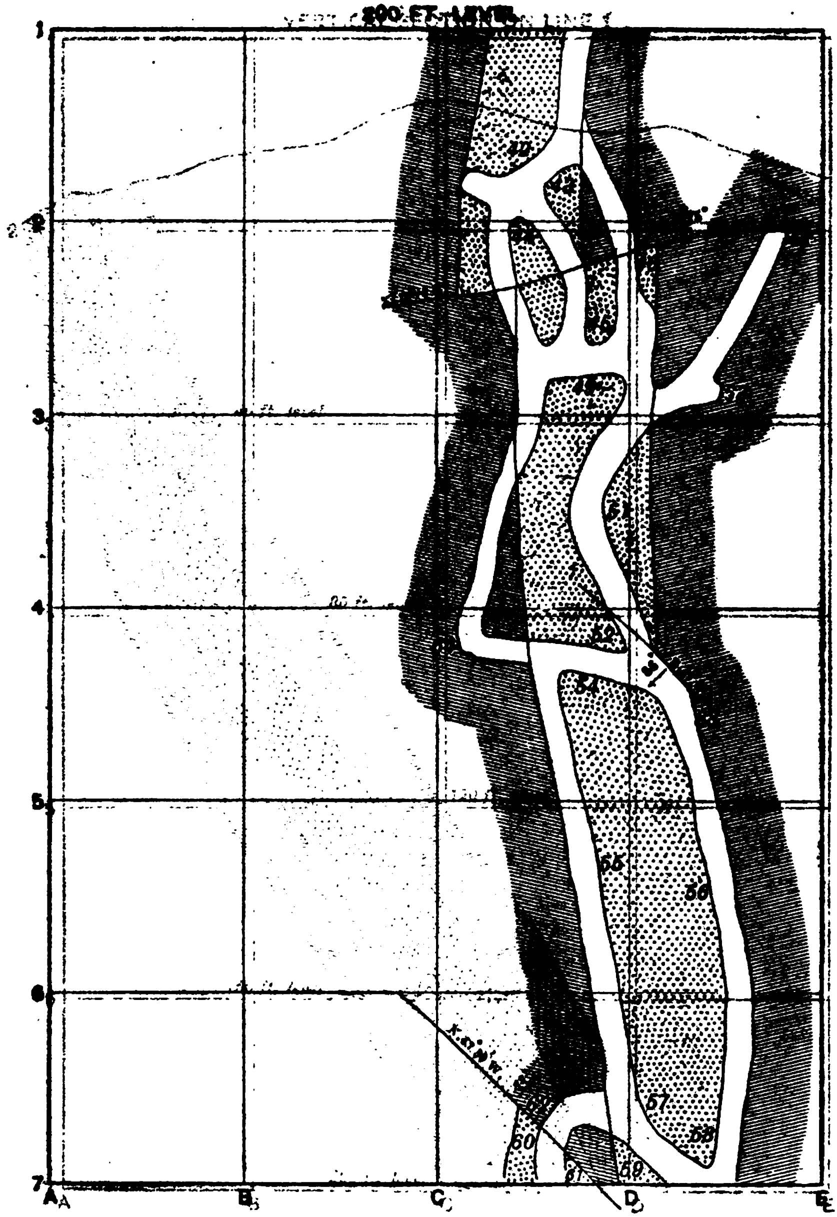


FIG. 66.

LEGEND

400 FT. LEVEL

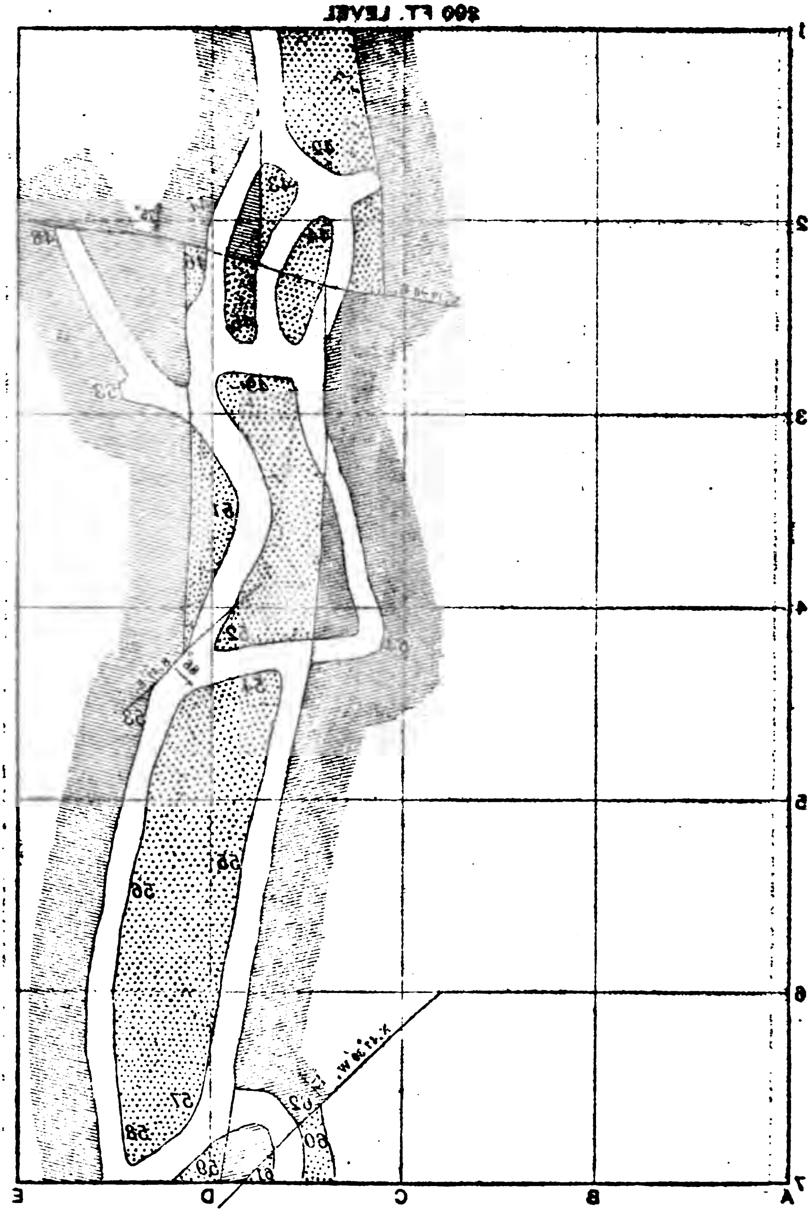
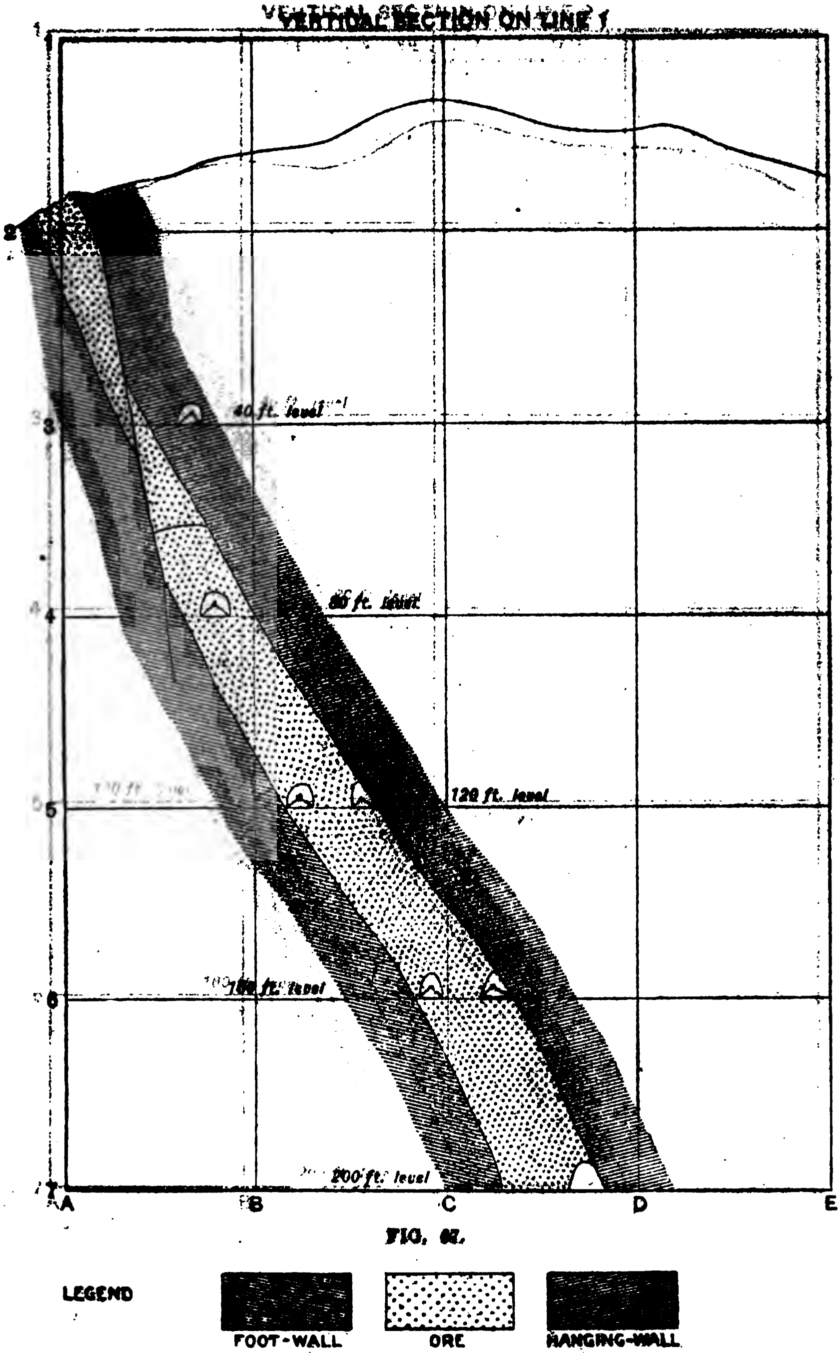


FIG. 66.



VERTICAL SECTION ON LINE 1
1
2
3
4
5
6
7
40 ft. level
80 ft. level
120 ft. level
160 ft. level
200 ft. level
A
B
C
D
E

FIG. 62.

LEGEND
FOOT-WALL
ORE
HANGING-WALL

VERTICAL SECTION ON LINE 1

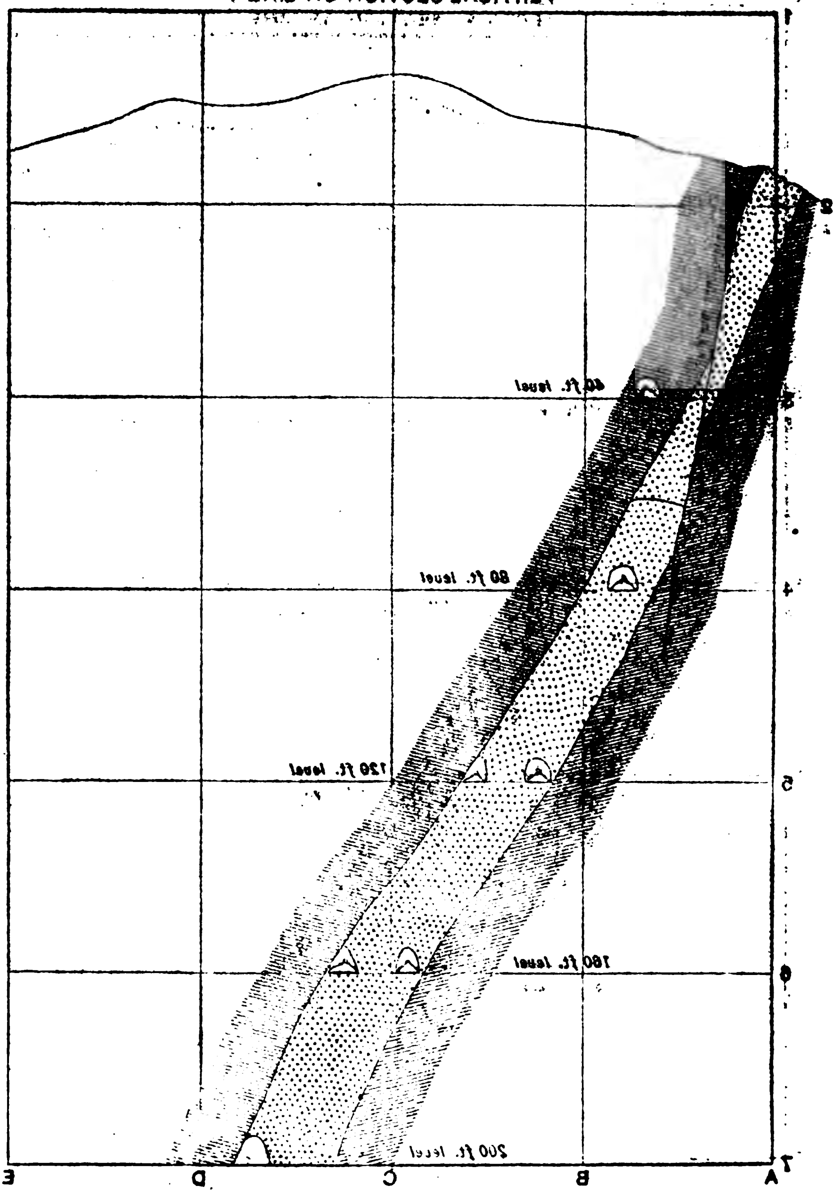
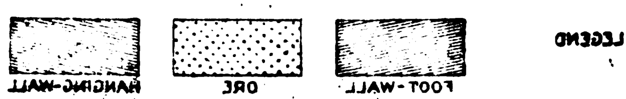


FIG. 67.



VERTICAL SECTION ON LINE 2

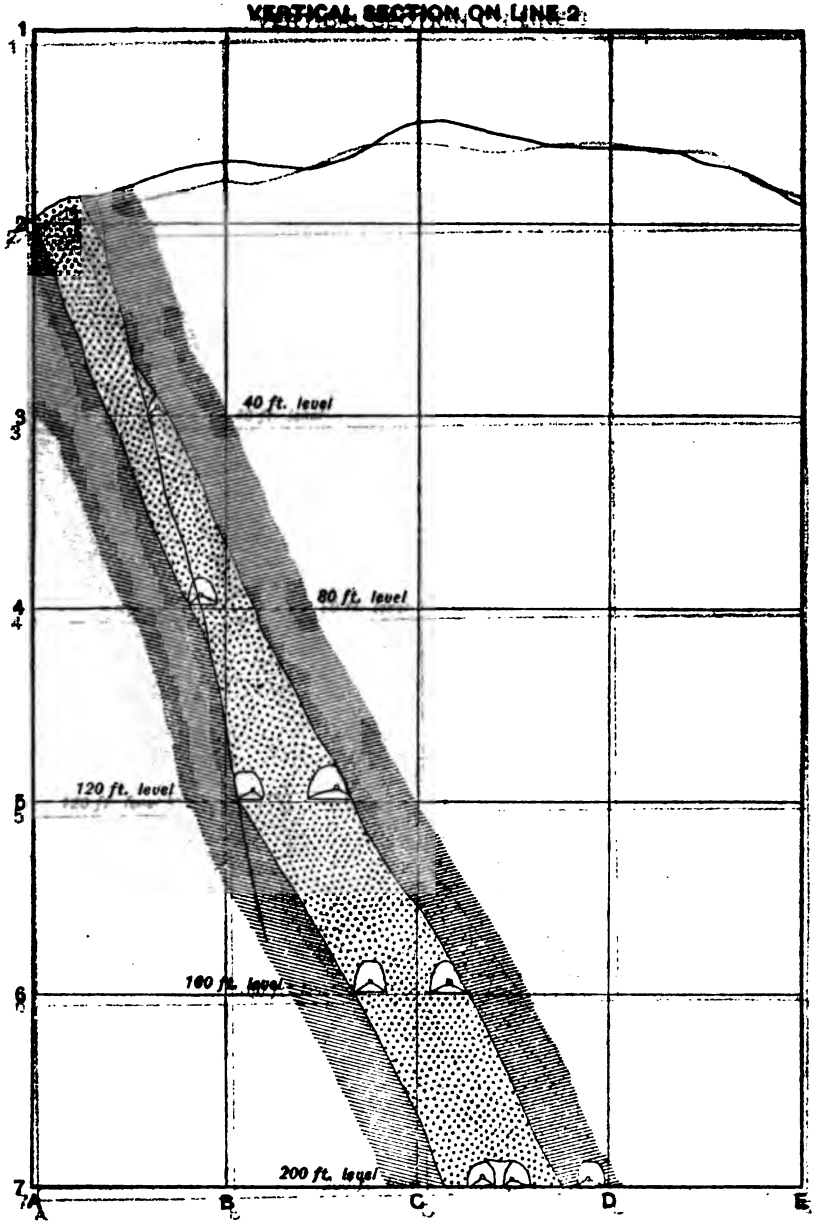


FIG. 68.

VERTICAL SECTION ON LINE 2

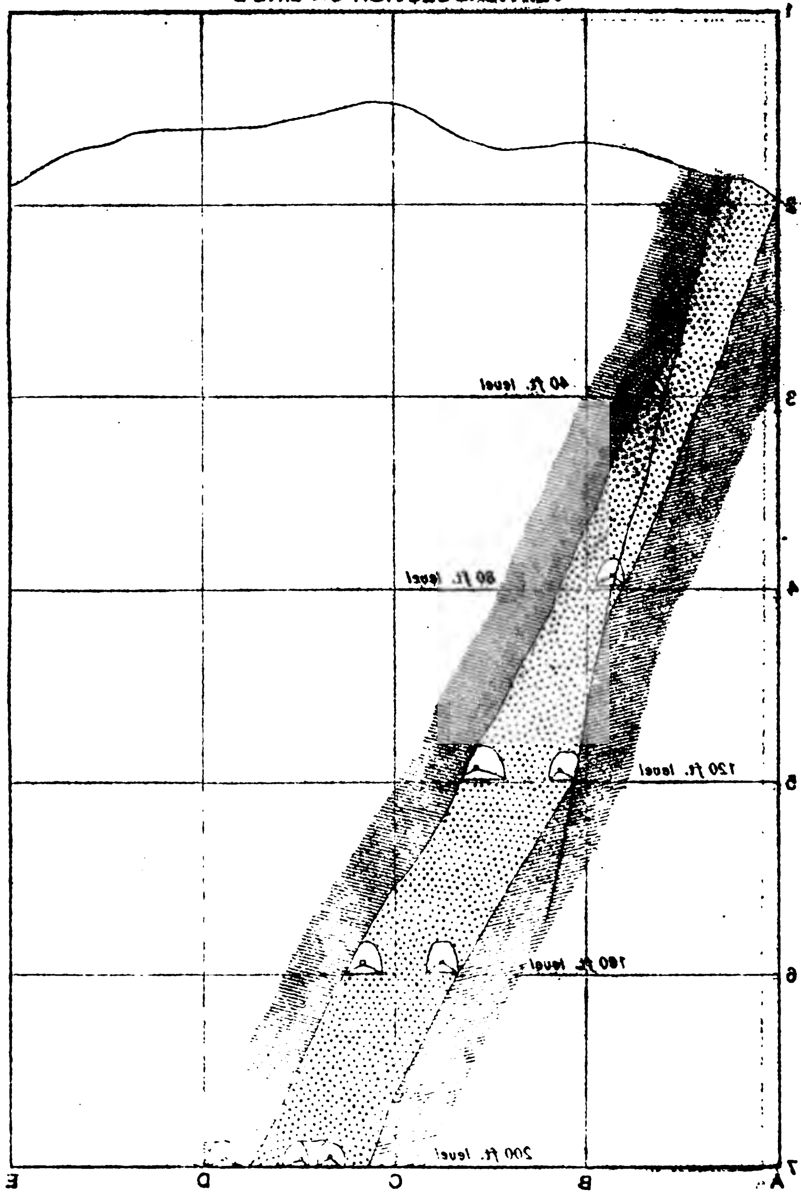


FIG. 68.

VERTICAL SECTION ON LINE 8

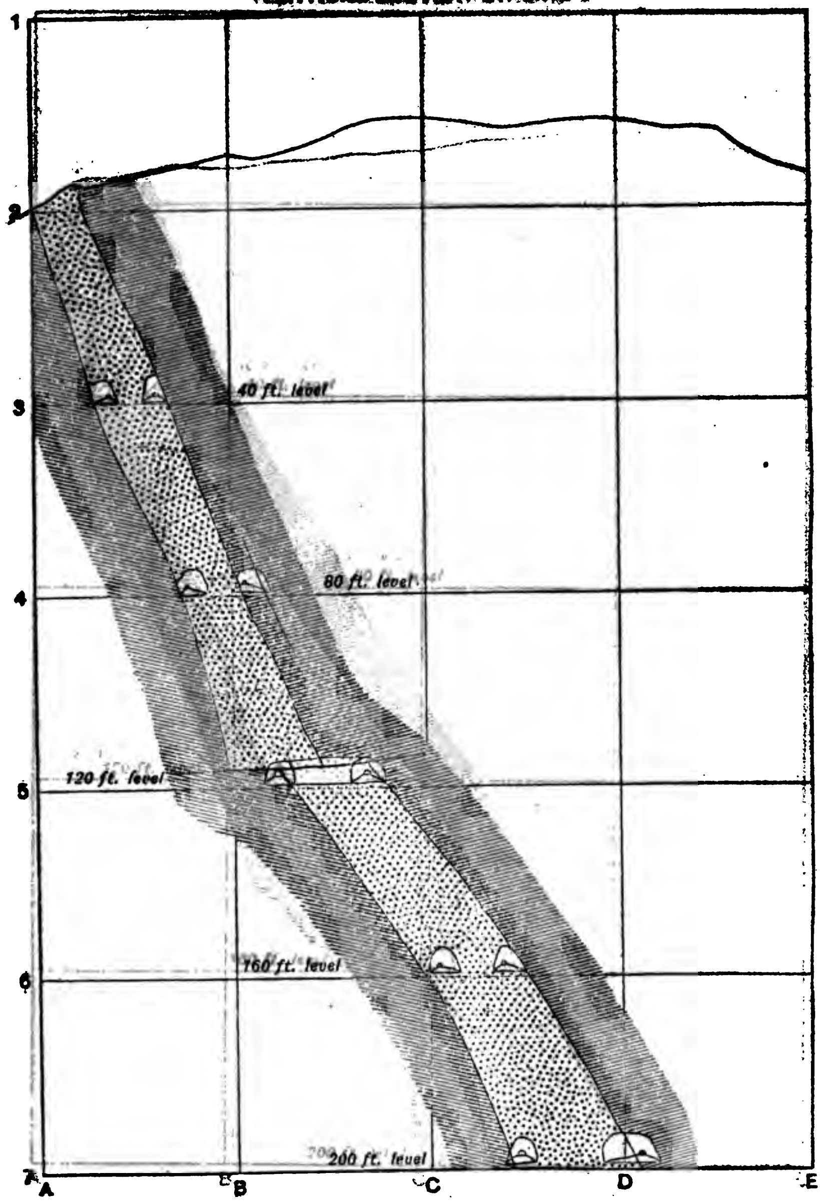


FIG. 69.

VERTICAL SECTION ON LINE 9

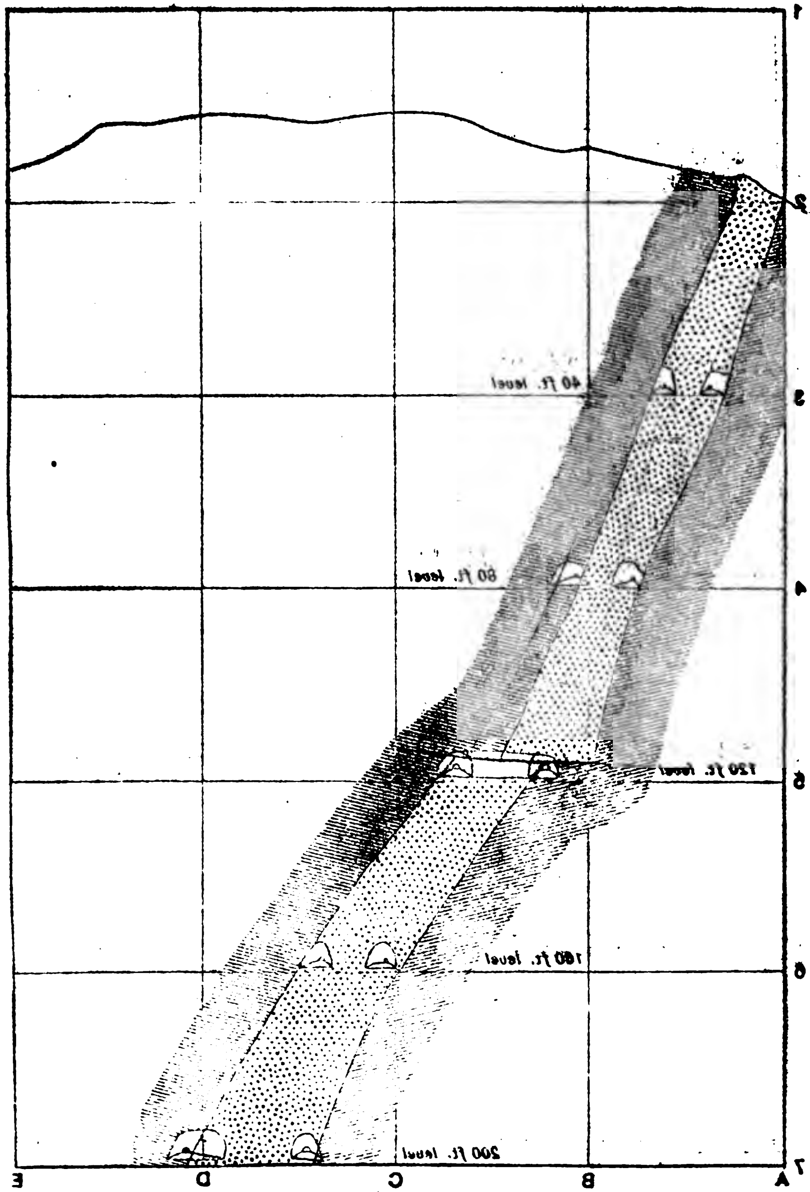


FIG. 69.

VERTICAL SECTION ON LINE 4.

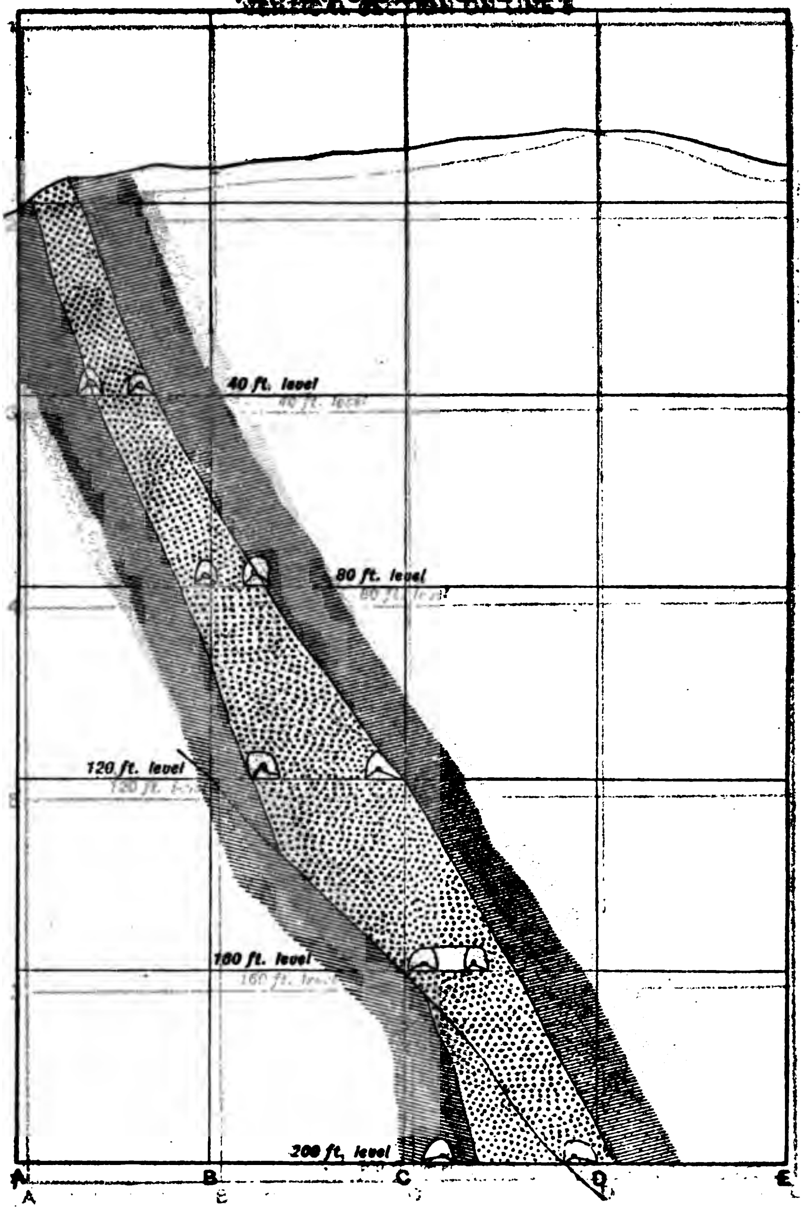


FIG. 70.

VERTICAL SECTION ON LINE 4

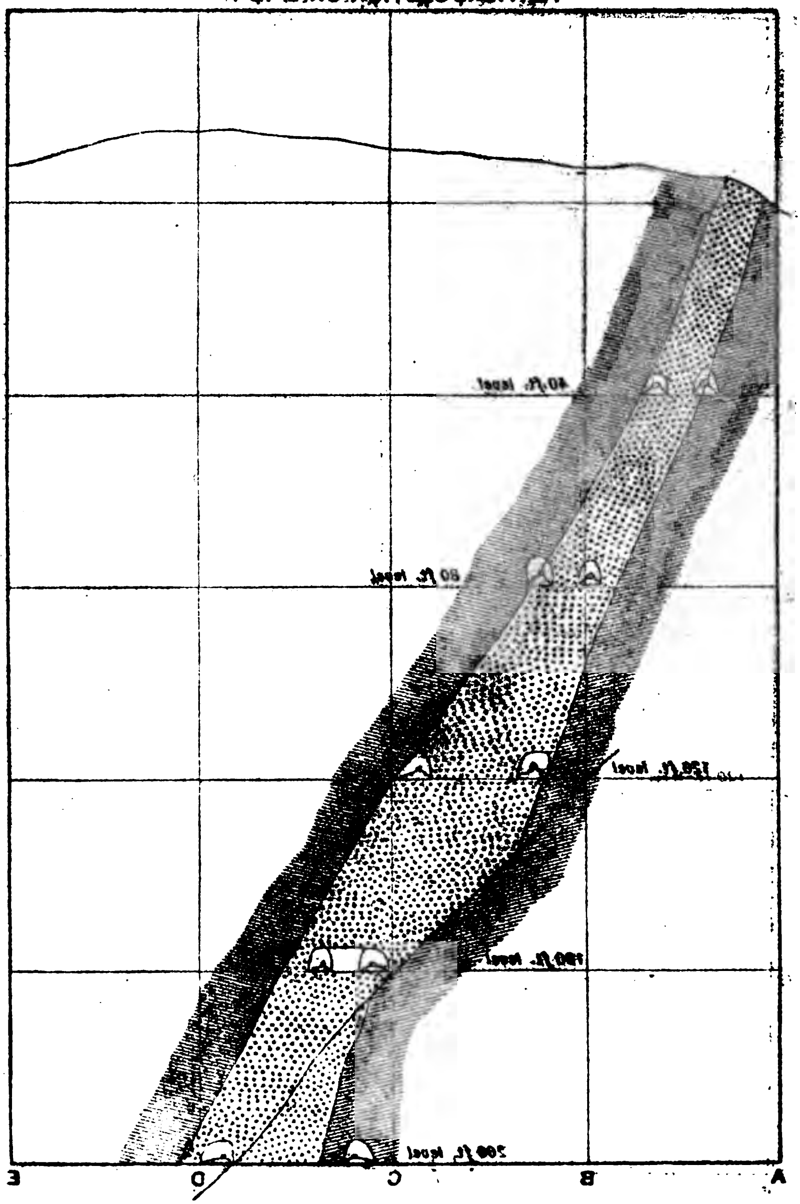


FIG. 70.

VERTICAL SECTION ON LINE 8

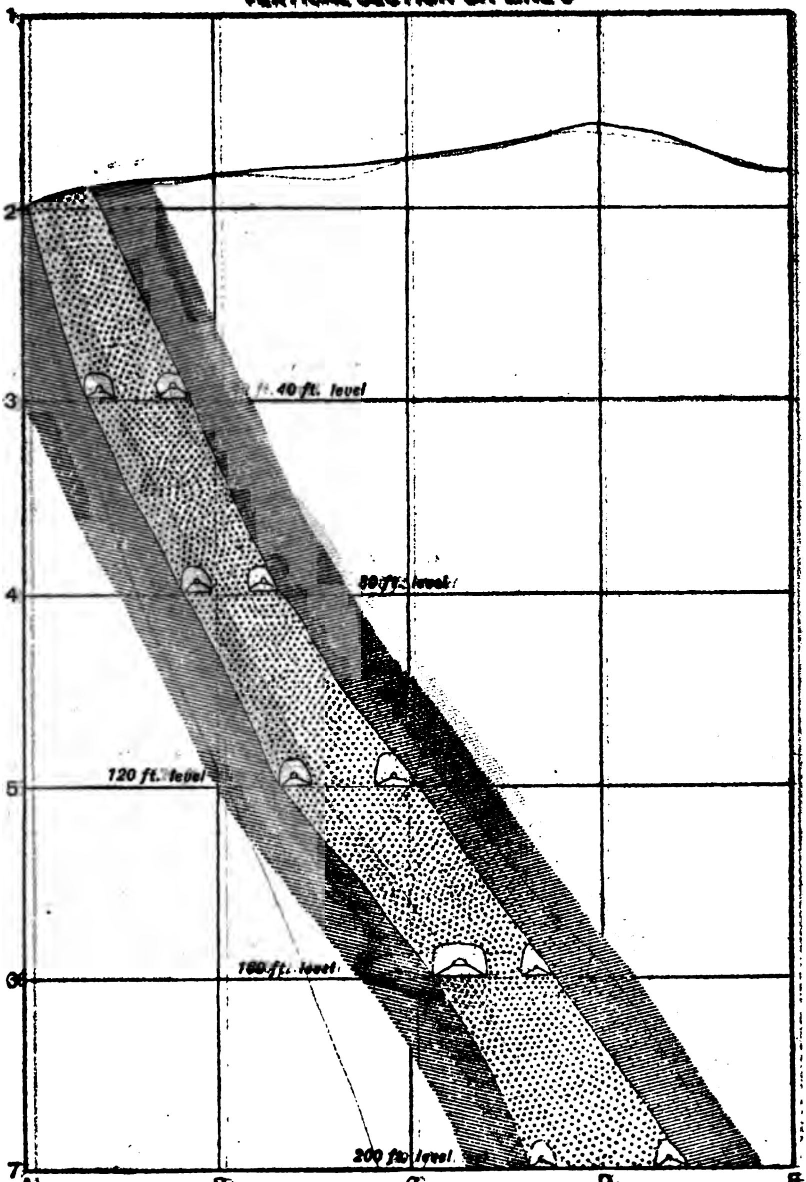


FIG. 72.

VERTICAL SECTION ON LINE 5

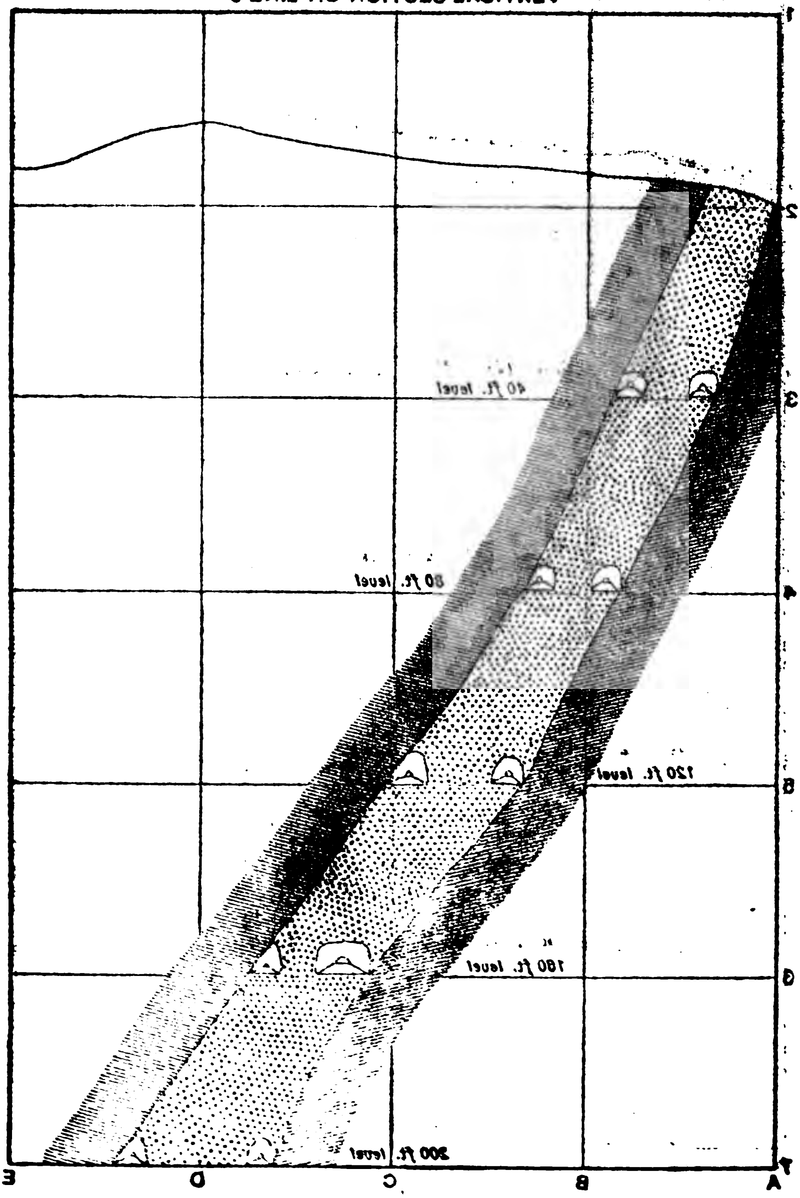


FIG. 71.

VERTICAL SECTION ON LINE 5

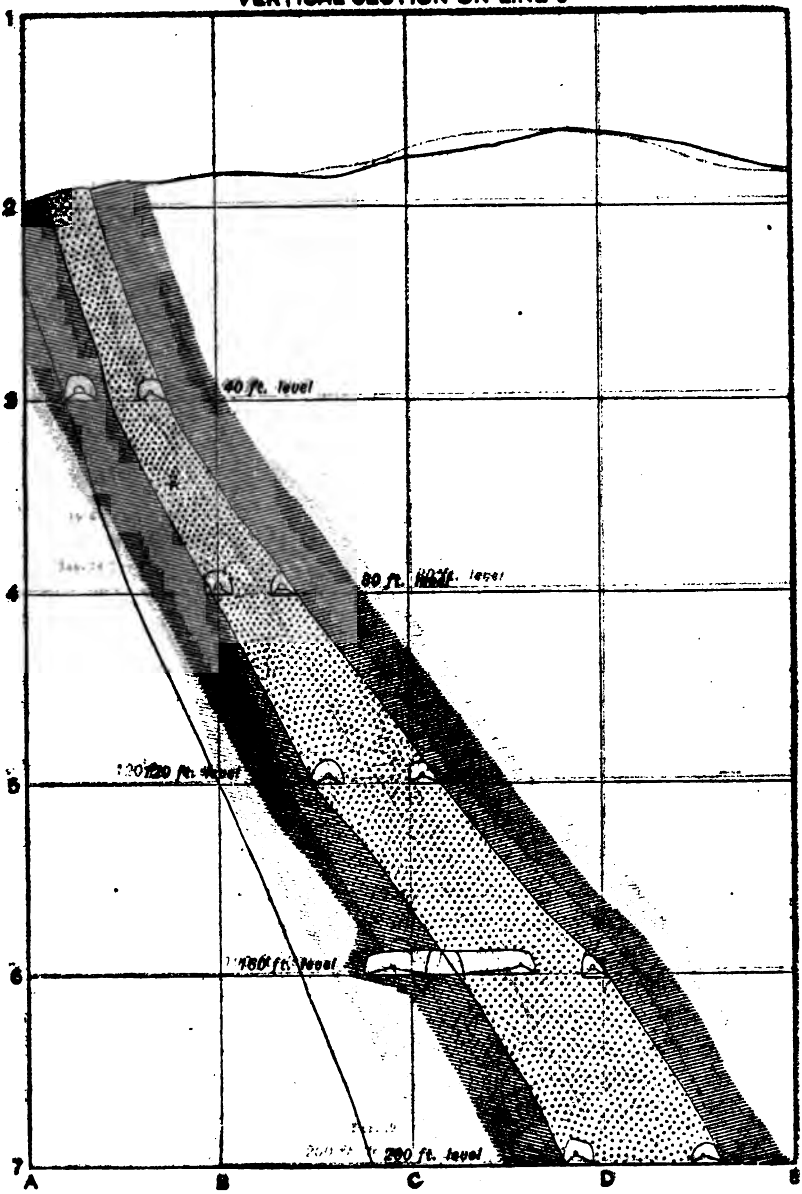


FIG. 72.

VERTICAL SECTION ON LINE 7

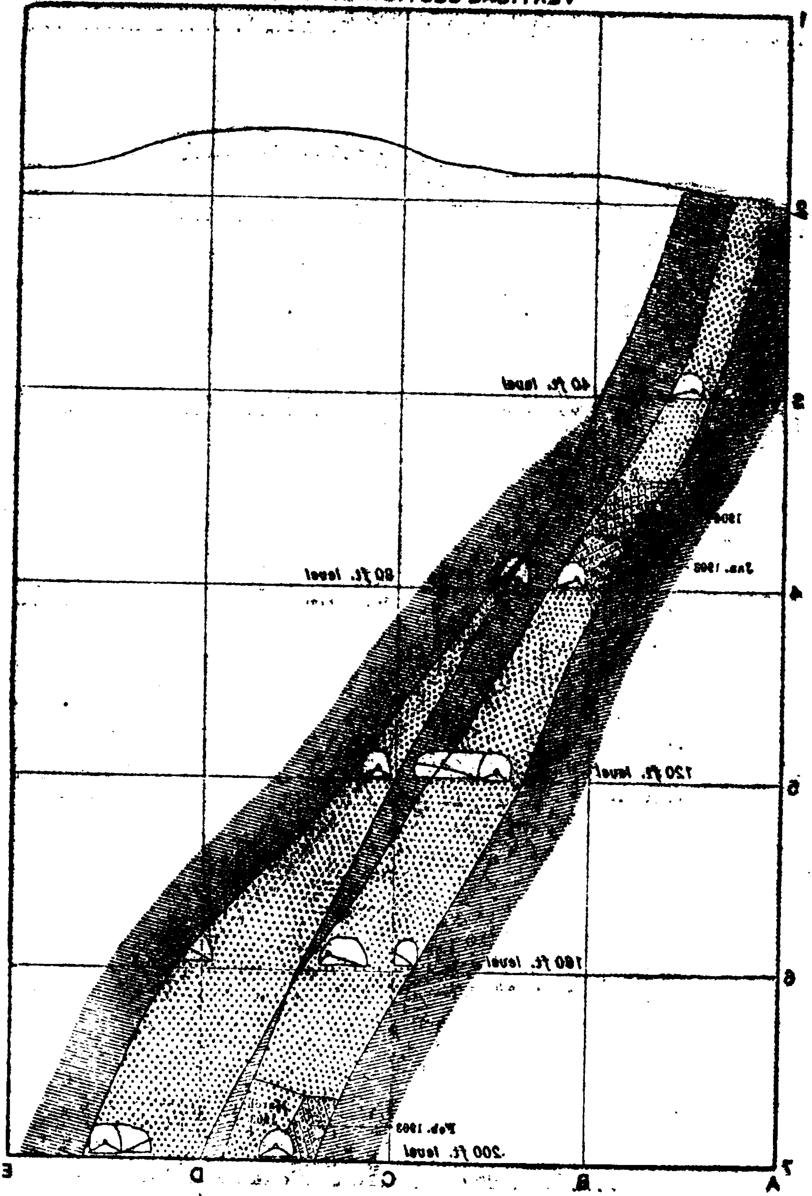


FIG. 72.

survey map, after which the geology, as exposed in the openings and determined by careful examination, is platted on the map, care being taken to note the strike and dip of all faults, spurs, and intersecting veins. Tracing cloth is always used for these maps, both for speed and convenience in tracing from the working survey map, and for the further reason that, when the level-sheets are in the holder, at least three sets of levels can always be seen through the translucent cloth, thereby affording an opportunity to determine the dip and trend of the ore-shoots, and consequently to project new workings with much greater ease than if observations were limited to a single sheet.

'Fig. 60 (the surface map) shows the outcrop of the ore-body a little farther west than the line of the 40-foot level in Figs. 61 and 66.

'Figs. 67–73, are vertical sections showing workings and geology. These sections, taken directly from the horizontal level-sheets, afford a very convenient means of studying the vein-structure and at the same time of keeping a record of the ground stoped during each calendar month.

'In addition to these advantages, the vertical sections afford an almost perfect check on the geology, which is nearly always noted first on the horizontal levels. Any errors, either in observation or interpretation, that may have crept into the geologist's work are sure to be detected when the vertical sections are platted.'

J. D. Kendall writes the following regarding geological mine maps, in the *Mining Reporter*, Vol. XLVIII, p. 181:

'When accurate plans, sections, and projections showing the topography have been prepared, the geological observations necessary to a clear comprehension of the structure of the ground in, and adjacent to, the mine may be made and accurately recorded upon them. Usually this most important part of a mine-plan is omitted, the topographical skeleton being considered sufficient. As a consequence, we find all kinds of ridiculous mistakes being made which would have been avoided had the structure of the ground been properly studied and recorded on the topographical drawings. It may be said that the geological features bearing upon the development of a mine are, and must of necessity be, often studied by the management, although the observations are not recorded on any plan. Such a statement, it is submitted, amounts practically to saying that such studies are of the most

perfunctory character; for it is impossible that any human being can produce a true mental picture of all rock-changes, faults, dips, bearings, and distances that occur in a complicated mine, so that all the relations and correlations of important features may be carefully studied. But even if this were possible, a further difficulty remains; it is impossible to lay on that mental picture a protractor and scale, by the help of which a competent person may, from a consideration of facts of observation, properly recorded on an accurate drawing, arrive at facts of inference which will be of the greatest value to him in the future working of his property; they disappear with the man who made them, and are useless to those who follow in the management; whereas, observations carefully recorded, on properly prepared drawings, remain for the use of whomsoever they may concern. Furthermore, we all know that observations that have to be recorded are much more likely to be accurately made than those which it is not intended to commit to paper.

'In recording the observations as suggested, there is not only a great saving of time through preventing work already done having to be gone over again, but it will often happen that facts which may be of great value in the development of a mine are obliterated in the process of working, so that if a record is not made of them at the time, they are lost forever.

'It is scarcely possible for a man to have studied the structure of ground in and about a mine without forming opinions as to the possible structure of parts then inaccessible, but in which it is hoped extensions of the deposit then being worked may afterwards be found. Such opinions, it is perhaps unnecessary to say, should not be formed on insufficient data, nor without the fullest consideration of the observed facts, but when they are formed, great care is necessary that they do not influence in any way the future observation and record of facts. It is necessary that opinions should be formed as to the unknown parts of a mining property, but the value of those opinions — assuming them to be logical — will depend upon the accuracy with which the facts have been observed and recorded. It is, therefore, all important that these be made with the greatest possible care, and without the least inclination to twist them into agreement with any prepossessed idea. From time to time, as facts accumulate, it may be necessary to modify, to a greater or less extent, the opinions formed on less

complete data. The lines used to set forth opinions on plans, should be different from those employed to represent facts. In most cases it is desirable to make the former with lead pencil only, so that they can be easily removed when necessary, and so that they may not, by any possibility, be mistaken for records of facts.

'Some of the information it is desirable to have on a working plan may now be mentioned. The nature of the enclosing rock or rocks should always be stated, and the extent of the different kinds of rock should be shown. In the case of sedimentary rocks, the dip should be frequently given. The foot and hanging walls of veins, and all faults, dykes, and lines of contact should be shown. Pay-streaks should be recorded, with as much detail as possible as to "horses," etc., occurring in them.

'Doubtless it will be said by those who do not appreciate the value of technical precision that all this work costs money, for which they do not see any adequate return. In mines which are provided with a surveyor and assayer there would be no additional cost; it would merely be a question of organization. Those mines that are without a surveyor and assayer will very often do well to get one. It will generally be economy to go to that expense unless the manager can do such work without interfering with his other duties. Those who decline to adopt such a course on account of the expense will doubtless fail to realize how much money they annually waste in making drifts, etc., which never should be made.'

Old Workings

The necessity for keeping complete and accurate maps of underground mine workings is frequently emphasized in striking ways. Often old workings become filled with water, and where no correct maps are made and retained, their location is unknown, and new workings break into them, resulting in destruction of property and death of miners. Twelve men were drowned in a coal mine at Jeansville, Pa., from this cause. Ten were once drowned in Colorado. Two were once drowned in the Cold Spring mine of Boulder county, who would not have lost their lives had an accurate underground map been kept of the workings on the neighboring Red Cloud vein. The old workings on the Bobtail at Black Hawk, whose exact location was unknown, caused an expenditure by the company of thousands of dollars to locate them.

In the Bull-Domingo of Custer County, Colo., the water in old and unknown workings broke into a drift and flooded the mine. The absence of the miners at dinner was all that prevented loss of life.

The neglect to keep such maps is often a good illustration of the strong tendency toward underrating the value of the work of the surveyor and assayer. They belong to the scientific department of mining, and it is quite popular now to exalt the importance of the purely practical miner at the expense of science.

Assay Maps [1]

'An assay map is a graphic illustration, plotted to scale, of the amount and value of ore in a mine. There are many ways of accomplishing this, the simplest perhaps being shown. In both examples the drifts and adits are represented as being straight; the uneven line above the levels and to the right of the vertical connections represents the widths of the ledge at the respective places, while the line under the levels and to the left of the raises represents the values. These lines may both be on the same side, one dotted and the other red, or both red, on different sides.

'The question may be asked what these maps show. It simply puts before one's eyes the mine in its commercial dress, for it shows the figures of a mine's value and the chances of future bodies of ore. It may prevent the pernicious habit of averaging, where one high assay will bring up unpayable ore sufficient to deceive one not familiar with mining and the vagaries of formations. Now, look at Fig. 74. This shows a ledge uneven as to widths and values, but continuous as far as developed. In this ore shoot, which trends to the right as we go down, are three different swells, which appear to be well defined. It shows a small ledge with high values, a proposition for a 5- or 10-stamp mill. Now, where one is informed that this ledge is on a contact of granite and a diorite dike, the mine and its chances form a clearer picture than a mere list of assays. These assays were taken between walls at every 5 feet, and where the formation was at all broken or soft, a proportionate quantity of waste was allowed in the sample to offset the difference between theoretical and actual mining. It is needless to say that this mine was developed before any milling was done.

[1] Algernon Del Mar, *Mining and Scientific Press*, September 3, 1904.

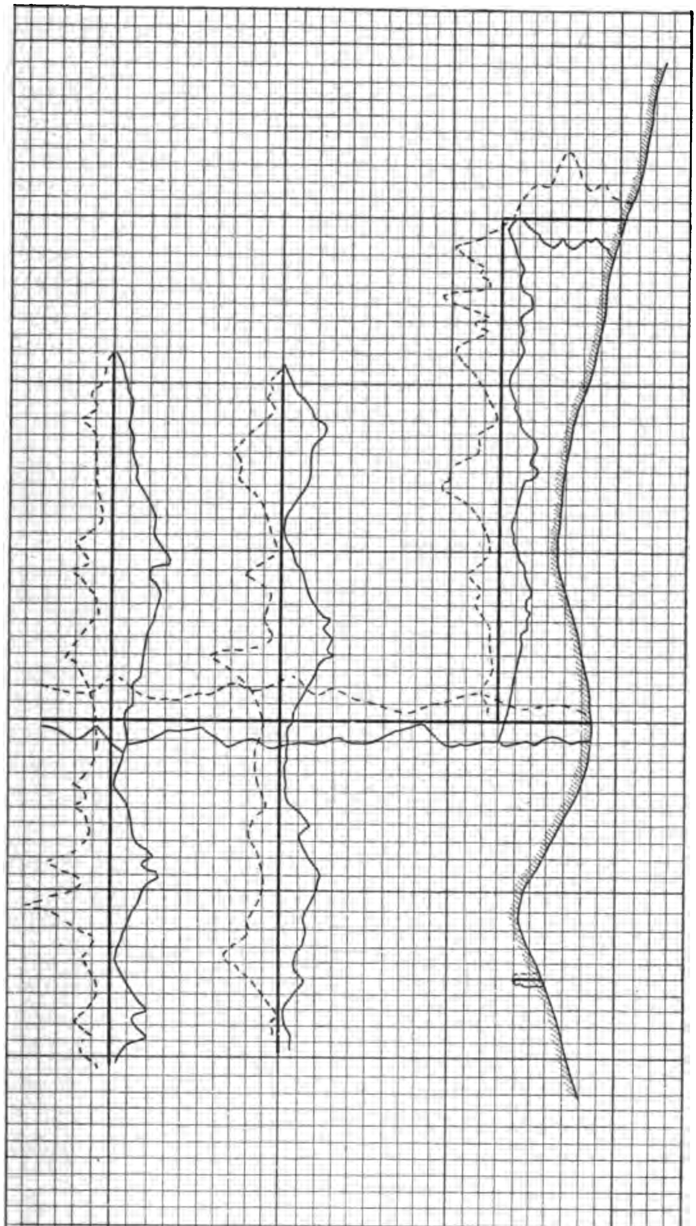


FIG. 74. — ASSAY MAP.

'In Fig. 74 the dotted and straight line over the workings (*A B*) shows width and values of outcrop.

'Fig. 75 shows a mine with irregular bodies of ore irregularly distributed, but with some uniformity in this irregularity, for these bodies or lenses occupy certain planes, and one is led to expect ore at *M* and also by continuing the adit *E*. It also shows that, these bodies of ore being small and limited, the levels should be run correspondingly close. It indicates a mine with a ledge in all the workings, presumably a fissure vein, the swellings only containing ore of sufficiently high grade to pay. It also shows at *F*, in adit *C*, how one can be deceived by taking assays at random for here is an $80 assay, while on either side is ore too low to pay. To make sure of this, a raise was put up, showing it to be a "freak" only, or, at best, an isolated spot of enrichment.

'One would be surprised to know what a great help a map like this is to a mine superintendent or to the directors, for it pictures at a glance the whole aspect of the mine.'

Assay Plan an Aid in Developing. — It is a well-known geological fact that ore bodies are lenticular in composition as well as in structure. That the assay value is highest at some one point and gradually lessens with distance from that point. Now suppose that a prospecting drift shows that the low values gradually become greater as the drift is extended, up to a certain value which is, however, too low to pay for extracting, and then gradually decrease again to the normal minimum. Now if these assays values are not mapped, and the manager does not watch the assay returns exceedingly closely, this rise and fall in value of unworkable ore is not noticed. In any case, if the clue is not acted upon at once, the chances are that it will be entirely forgotten and never acted upon.

It may be, of course, that the increase in value means nothing, but the chances are that the drift has passed through the outer part of a lens of pay ore. Whether the workable part of the lens lies above or below the drift can only be determined by upraise and winze. Neither may find ore, but the management which does not make the exploration is bad. The secret of the success of many men who are said to be 'able to see into the rock' lies in the above.

It is, then, evident what a help, if not an actual necessity, the assay plan is to the manager. To be sure, the information may all

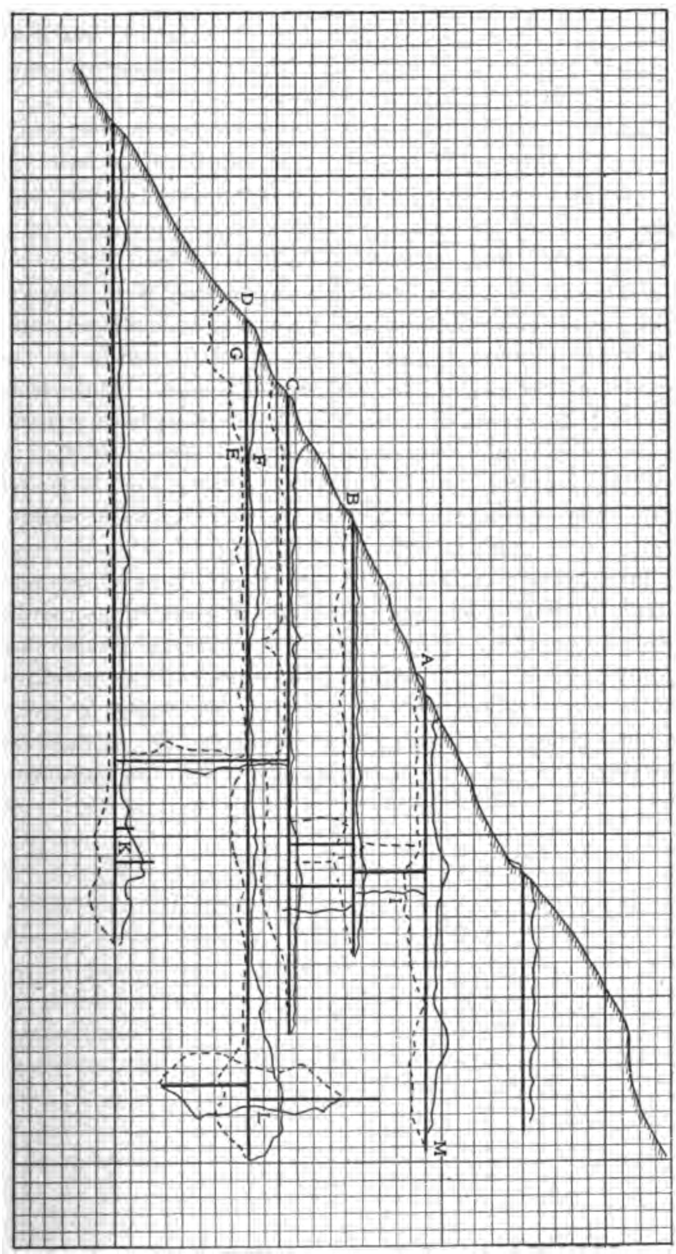


FIG. 75. — ASSAY MAP.

be ferreted out of the ordinary assayer's record book, but it must be searched for before it is noticed. If the assay values are platted, however, they cry aloud for recognition.

Not only do the actual assay values deserve notice, but the mineralogical character of the rock and vein stuff as well. It is a matter of comment that miners are often able to enter an old 'worked-out' mine, as leasers, and in a short time open up new ore-bodies. They had noticed 'symptoms' which had escaped the management at some former time when they were working in the mine. Had all geological and mineralogical changes and the assay values been mapped, the ore-body would probably have been opened and extracted for the company's benefit. And, incidentally, the reputation of the manager would have been enhanced.

In order to list the various uses of, and necessities for, mine maps it may be said that an accurate survey and large scale, carefully made, plans and maps are necessary for the following reasons:

(1) The laws of most States require them; (2) as a basis for the planning of mining operations; (3) in order to determine royalties; (4) basis for geological survey of the mine; (5) basis of assay plan; (6) in order to work inside of mine boundaries; (7) to avoid opening old workings which may be flooded with water or gas; (8) to establish grades for haulage and drainage; (9) to make connections between different mine openings; (10) to estimate ore reserves.

VIII

THE MAKING OF MINE MAPS

THE manner of making mine maps differs in no way from that of surface maps. As the maps are for use by the mine officials and not for show purposes, they are made as simple and as plain as possible. While no time should be grudged to making the most useful map, no time should be wasted in making it beautiful or artistic. That is, it should not carry an elaborate title or ornate border.

If a map is being made for public distribution or for court purposes, the above statement does not apply. In that case, everything to make a picture, and a pleasing picture, must be done.

The S. F., P. & P. Railway Co., issues a pamphlet entitled 'Instructions to Engineers.' While it refers, of course, to the mapping of railroad survey, the following quotation may be made applicable to mine maps.

'All tracings should be drawn on the rough or unglazed side of the muslin, and the muslin should be sufficiently long to leave 7 inches blank beyond the extreme limits of the drawing or writing on either end.

'The lines should be clear, uniform, and distinct, avoiding hair lines. They should be drawn only with good black ink, either well-ground India ink, or some good, prepared drawing ink, such as photo, black drawing ink of Keuffel & Esser, or "Higgins's" American drawing ink, and all figures should be uniformly written in the same black ink. The line of survey may be drawn in a good chemically opaque red, such as would result from the admixture of good cake carmine and cadmium. Colored inks should never be used upon tracings. Gamboge should never be used either alone or in combination.

'Where the line crosses a depression, ravine, or stream, the direction of the fall should be shown by an arrowhead pointing in the direction of the fall, unless it is clearly indicated by the topography immediately adjacent.

'On every map or drawing as near as practicable to the lower left-hand corner, there should be a title distinctly written, containing in addition to the distinctive name of the map or drawing, the scale, and the date on which the map or drawing is made. Also on maps a plain diagram indicating the true meridian and the magnetic, the magnetic variation being given if known, and if not known, deduced from some prominent course on the map, and indicated in connection with the magnetic meridian.

'The words "Map of," "Profile of," in titles would better be omitted, and "Preliminary Survey," or "Location Survey" substituted, as it is presumed that those having business with drawings will be sufficiently familiar with them to distinguish.'

Size and Scale

Regarding the scale to which maps should be made, it can only be said that the scale must be selected to best suit the purpose of the map and the mining and geological conditions of the property. The size of the map is, of course, dependent upon the size of the property, and the scale to which the map is drawn.

While a large sheet of paper is awkward and difficult to work upon and to keep neat, there is a tendency among engineers to have the whole map upon one sheet of paper. The map can undoubtedly be split up and drawn in sections upon reasonable-sized sheets. These are made to match, and blue-prints taken from the tracings can be pasted together into one sheet if desired. The variety of sizes of maps, and of scales can be seen by noticing those used by the different mining companies whose practice is described on pages 175 to 210.

Methods of Platting Angles

There are various methods used to map the survey notes. These all are based upon some method by which an angle may be platted. The various methods used vary in accuracy and in the time required to do the work. The accuracy required in a map, and the proposed cost of it, therefore, determines which method shall be used.

But four methods will be noticed here. They are the methods by use of: (*a*) Protractor, (*b*) tangents, (*c*) chords, (*d*) coördinates.

By Protractor. — The accuracy of the work done by the protractor method must, of course, be directly proportional to the size and accuracy of the protractor used. One would not expect to do as good work with a 4-inch paper protractor as with a large limb protractor whose vernier reads to minutes of arc.

The protractor method used by the United States Surveyor-general's offices is probably the best. The paper used for maps has the degree and minute marks printed along the edges of each sheet. The centres are at the corners and any bearing may be laid off directly from these protractors. To carry the line to the required point on the paper, long heavy parallel rulers are used.

As the protractor method is quick, it is frequently used for platting of side-shots or other unimportant courses, even when the traverse lines are platted by means of coördinates. In coal-mine mapping, in particular, the protractor is much used. With a good limb and vernier protractor, better and quicker work can be done than by either the methods of chords or tangents.

By Tangents. — To use this method, one must have at hand a table of natural tangents and cotangents. The angle is laid off each time from the meridian or the east-west line drawn through the station. When the bearing is less than 45°, lay the base off along the east and west line and use the cotangent times the base for the altitude. The hypothenuse of the triangle is then, evidently, the direction of the new course and the distance is measured off along it to scale.

Any length may be used for the base of the triangle, but it is convenient to use either 10, 100, or 1000 to scale, for the altitude, a, is read directly from the table on natural tangents by setting the decimal point over one, two, or three places as the case may be. The larger the triangle, the greater the accuracy of the angle, other things being equal.

This method is quite accurate where the triangles used are large and the altitude of the triangle is truly perpendicular to the base-line. The method is necessarily somewhat slow, owing to the number of operations required. It also is open to the objection that the map becomes very mussy from the great number of pencil construction-lines used.

By Chords. — This method is very similar to the tangent method. Instead of erecting a perpendicular at the far end of the

base-line, an arc whose centre is the station at which the angle is required and whose radius is equal to the base-line, is struck off. The length of the chord (c) which will subtend the angle a at the centre, is then found from the tables of natural functions, and the formula, $c = \sin \frac{a}{2} \times$ length of base-line $\times 2$. It is here convenient to use a base-line of 5, 50, or 500 so that when the natural sine of $\frac{a}{2}$ is found, it may be multiplied mentally by 10, 100, or 1000, to give the length of 'c.' Having determined the length of the chord, it is laid off on the arc and the third side of the triangle drawn.

In all the methods yet discussed, the degree of accuracy is a function of the scale to which the map is drawn. When the scale used is 100 feet to 1 inch, a pin-prick covers 1 square foot, and at the circumference of an 8-inch circle, it covers 10 minutes of arc. Each course plotted will then certainly be in error by at least 1 foot in length and 10 minutes in bearing. If now the errors be all in one direction, the error in length, after plotting 100 courses, will be 100 feet, and the error in bearing will be 1000 minutes or 16°. Fortunately, however, these errors are in different directions, and only part of them remain uncompensated.

According to the theory that the square root of the whole number of readings is uncompensated, the final error will be $\sqrt{100} \times 1$ foot or 10 feet in length and $\sqrt{100} \times 10$ minutes or 100 minutes of arc. If each course be 100 feet in length, the final station will be about 70 feet in error, due to error in arc. Combining the two errors, one of 10 feet, due to length, and one of 70 feet, at right angles, to each other and the last station may be located $\sqrt{10^2+70^2}$ or 71 feet distant from the true point, in any direction.

When plotting by protractor, the above assumptions apply. When plotting by tangents or chords, the errors in arc are not cumulative, but the error in distance is. The location of the final station will be wrong by only 10 feet. When the possible errors in the meridian and east-west lines and the altitudes are considered, it is seen that the method is not so much more accurate than the protractor method.

The disadvantages of each of the three methods are: (a) The large scale required; (b) the many construction-lines which must be erased; (c) the absence of checks; (d) a failure to close a traverse may be due to an error in the field-work or in the mapping, and the

plotting does not show which; (*e*) as drawing paper shrinks and expands, work done upon the map at different times may really be to different scales. These many disadvantages have driven engineers almost everywhere to use the coördinate method wherever accurate work is necessary.

By Coördinates. — Before beginning to map up the notes, it is necessary to calculate the elevation and coördinates of each station. These calculations all appear in the calculation-book, and the results are copied into the ledger and field-book.

The slope distance is first reduced to the horizontal distance by multiplying it by the cosine of the vertical angle. The slope distance into the sine of the vertical angle gives the vertical distance. The elevation of the previous station plus the H. I., the vertical distance, and the height of foresight, each with its proper algebraic sign, gives the elevation of the new station. The elevation is used as one coördinate. In mapping, it appears only in the elevation or section drawings.

The two horizontal coördinates are the sums of the latitudes and departures of all courses extending from the point of origin to the station in question. Before calculating latitude and departure of a course, one must check the single and double readings of the angle turned, for a one-half minute angle subtends one-tenth of a foot of arc at a distance of 700 feet, and must be considered, if present.

By this method, an error in the location of one point in no way affects the correct location of the rest. But few construction-lines are drawn. The distance between two plotted points is measured and should check the horizontal distance of the notes. No measurements of over 4 inches (actual) are made on the map, so that the shrinkage or warping of the paper causes a minimum of change in scale. The method is quick and not conducive to error, after the calculations are made, and the calculations are those which have to be made sooner or later, no matter what method of plotting be used. The beauty of this system of plotting and of keeping notes is best realized when one has to calculate the connection of points on two different levels and each distant from the nearest shaft or chute.

The bearing of the course is now calculated and the latitude and departure calculated by multiplying the horizontal distance into the tangent and cotangent of the bearing angle. These added

to the coördinates of the last station give the coördinates of the new one.

The paper which is to be used for the map is first ruled off by means of fine lines into squares which are 200, 500, or 1000 feet to the scale of the drawing on a side. These lines are numbered according to their distance from the point of origin. The actual location of a point at which a station is mapped is then done by measurement from the sides of its own square. For example, a station which is 9373 feet north and 1272.5 feet east of the 0–0 point, will fall in the fifth square above and the seventh to the right of the 0–0 point on the map, if the red lines are drawn 200 feet apart. To locate the point in the square, an east and west line is drawn across the square 137.3 feet above lower side and the point marked upon it 72.5 feet from the left-hand side.

If a, b, and x represent the three coördinates of one point, and c, d, and y those of the other, then the bearing of the second from the first is evidently the angle whose tangent is $\frac{a-c}{b-d}$ and the horizontal distance is $\sqrt{(a-c)^2+(b-d)^2}$. The difference in elevation is $x-y$ and the slope distance between the points is $\sqrt{(a-c)^2+(b-d)^2+(x-y)^2}$. Likewise, the vertical angle must be that angle whose tangent is $\frac{x-y}{\sqrt{(a-c)^2+(b-d)^2}}$.

The coördinate method is superior to every other method, and it has no disadvantage peculiar to itself.

Bibliography: Maps and Mapping. — Map of Flat Coal Veins, *Eng. and Min. Jour.*, February 11, 1904; Better Methods, *ibid.*, January 19, 1907; Ventilation Shown on Maps, *ibid.*, May, 1895, p. 222; Accurate Underground Plans, *British Col. Min. Rec.*, July, 1902; Accurate Underground Plans, *Canadian Eng.*, May, 1902; Surveying and Mapping, 2d *Penn. Geol. Surv. Coal Mining,* "A. C." p. 369; Mine Plans, *Mining Reporter*, vol. xlviii, p. 165; Use of Mine Maps, *ibid.*, September 3, 1902, p. 202; Assay Plans, *ibid.*, October 3, 1903; Mine Maps: Geological Use of, *ibid.*, August 21, 1903; Mine Maps, *Mines and Minerals*, February, 1901; Assay Maps, *M. and Sci. Press*, September 3, 1904; Assay Values, Graphically Shown, *ibid.*, March 28, 1903; Improved Form of Protractor, *Trans. A. I. M. E.*, vol. xxv, p. 650.

IX

PRESERVING OF MAPS

At many mines one finds but one map, and it hanging in the dust and dirt of the office, or rolled up and laid upon some shelf or table. The original map should not be used as a working map subject to daily fingering and soiling. Blue-prints should be taken off for reference and the original map kept safe from wear and dirt.

Many schemes for the filing of maps have been tried. For large maps it is almost necessary to roll them. The roll, if slipped into a tin cylinder with end-caps, will be protected. These cylinders may then be named or numbered and put away in racks. For smaller maps drawers or vertical filing cases are convenient. The manufacturers of sectional bookcases list sections for map- and drawing-filing.

Where the mine map is brought up to date each month and blue-prints taken, a file of the blue-prints is often a great convenience to show the condition of any particular part of the mine at any particular date.

Several engineers have published accounts of methods of map- and drawing-files used by them. The description of one of the more elaborate systems is given below.

A System of Map Filing[1]

'Maps and drawings of different sizes are filed in different-sized and shaped pigeon-holes and drawers. These are all catalogued in an ordinary surveyor's field-book so that each may be found by reference to the catalogue rather than to labels on the files.

[1] G. N. Pfeiffer in *Mining and Scientific Press,* November 9, 1907.

'The catalogue is divided as follows:

				No. of Map	Page
Mining	Surface	Denouncements	Company's	0– 100	22– 26
			Others	101– 500	27– 40
		Topographical		501– 525	41– 42
		General		526– 600	43– 46
	Underground	Plans		601– 750	47– 58
		Elevations		751– 800	59– 62
		Miscellaneous		801– 900	63– 68
	Timber			901– 950	69– 71
	Miscellaneous			951–1000	72– 75
Mechanical	Engines and boilers			1001–1100	76– 80
	Pumps			1101–1200	81– 85
	Foundations			1201–1240	86– 87
	Cars			1241–1270	88– 89
	Cages			1271–1300	90– 91
	Miscellaneous			1301–1500	92–101
Railroad	Cross-sections			1501–1550	102–103
	Plans of route			1551–1600	104–106
	Topographical			1601–1625	107
	Switches and frogs			1625–1650	108–109
	Trestles			1651–1675	110
	Miscellaneous			1676–1800	111–116
General	Real-estate and leases			1801–1850	117–118
	Buildings			1951–1950	119–124
	Electric installation			1851–1975	125–126
	Ore-bins			1976–2000	127
	All others			2001–2200	128–137

'The numbers of the second column under the heading "Page," refer to pages of the catalogue, where a description is given of each plat that comes under that particular division. The numbers in the other column refer to the numbers given to the plats; these are printed in red in the lower right-hand corner on the back; the number on each plat is the same as given with the description in the catalogue. Take for example an 18 × 20 inch blue-print of a one-horse whim. On the back in the lower right-hand corner of the blue-print is the number 2001C (in red), the C shows that this will belong in the left-end compartment. In the catalogue on page 128, make this entry, "2001C (in red). One-Horse Whim; print; 6–3–07." Next cross-index under "Timbering" and "Hoists" or "Engines," but then give the number 2001C in black. If the description is long, space can be saved when cross-indexing by only giving a key-word and the page where the full description is

made. For the catalogue an ordinary surveyor's field-book was used. Most of the maps are rolled and held by a rubber band, the other few are folded. Those that are folded all have the numbers in the same relative position.'

Models

Mine models are constructed of glass, wires, strips of wood, cement, and other materials. The idea of the model is to bring the relative positions of the mine workings clearly before the eye in one comprehensive whole. The engineer trained to the reading of maps is usually able to form a mental picture of the underground from a study of the maps, but the non-professional man must see a model before he can form this picture. It is surprising how little idea the average non-professional man will secure of a mine by walking through it. He immediately loses all sense of direction and gains no idea of the workings in their relation to each other. It therefore becomes necessary to draw him a picture, or construct a model for him to study, when he is a member of a jury and must understand the underground geography and geology before he is able to render a decision.

Models are usually constructed for court use only, but some mines find that it pays to keep the mine model up to date and use it when giving orders to foremen, timbermen, and trackmen. The Portland of Cripple Creek uses a model in this way and the chief engineer says: 'We could not get along without it.'

A model of glass is made by sliding sheets of glass into a frame which holds them horizontally and properly spaced so that each sheet represents one level. The workings are then painted upon the upper surface by laying the glass sheet over a map of that level.

Colors mixed with copal picture-varnish and linseed oil in proportions to flow easily and to dry quickly can be applied with pen or fine brush. If necessary, intermediate sheets to represent different floors above the sill may be inserted between the level-sheets.

Where a cross-section or section along a vein is desired, the glass sheet is hung up and the workings painted upon it the same as for the plans. The geology can be shown by conventional markings upon the glass.

The wire models are constructed by bending and hanging wires to represent the workings. A model of wire constructed for court use during the lawsuit between the Home and Champion Mines of Grass Valley, California, is on exhibition at the University of California. Almost every mining school has models which have been given to the school after their use in the court room had ended. The possibilities of models for use in the same way as the working maps has not been properly appreciated. For many mines, the presence of a properly constructed model would be a time-saver and a great convenience to all the officials of the property.

Bibliography: *Mine Models*.—Mine Models in Glass, *Col. Eng.*, August, 1895; Model of Alaska Treadwell Mine, *Cal. Jour. of Tech.*, April, 1904; Mine Models in Concrete, *Mines and Minerals*, May, 1907.

Erasures

Erasures can seldom be made without leaving a disfiguration on the paper or tracing cloth. When an erasure becomes absolutely necessary, it should be done with extreme care. If an erasure will save a drawing which would require hours of work to reproduce, do not grudge the time required to do a careful job. Use a sharp knife and pick the scales of ink off rather than scrape them off. A reading glass will be an aid in this operation. After the ink is all picked off, smooth the erasure down with a soft pencil eraser.

If the erasure has been made on a tracing, the gloss may be nearly duplicated by carefully rubbing the rough spot with a smooth piece of wax or an old phonograph record. Or a surface which will take ink nicely may be given to it by a thin coating of collodion.

Inks, Colors, and Washes [1]

'Bottled ink, which is prepared in various colors, is used extensively on engineering drawings. The so-called "waterproof" inks differ from other inks in that a water-color wash can be put over the lines without causing them to "run." Bottled inks are

[1] Breed & Hosmer.

satisfactory for most drawings, but when very sharp and fine hair-lines are required, it is well to use the stick india ink. This is made by grinding the ink together with a little water in a saucer made for this purpose, until the ink is thick and black enough to be used. If the ink becomes dry it can be restored to as good condition as when first ground by adding water, a drop or two at a time, and rubbing it with a piece of cork or a pestle; if the water is added too rapidly the ink will flake.

'While the bottled black inks are fairly well prepared, the red inks are very unsatisfactory. They will sometimes run on paper where only very slight erasures have been made; in fact, on some of the cheaper papers red ink will always run. For tracing purposes red ink is wholly unsatisfactory, as it is impossible to obtain a good reproduction of a red-ink line by any of the process prints. Where red lines are needed the use of *scarlet vermilion water-color* will be found to give not only a brilliant red line on the tracing, but also "body" enough in the color so that the lines will print fully as well as the black-ink lines. Scarlet vermilion water-color will give much better lines on any paper than the bottled red inks. Only enough water should be used to make the water-color flow well in the pen. Other water-colors are used in the place of the bottled, colored inks, such as *prussian blue* instead of bottled, blue ink, or *burnt sienna* instead of brown ink, and these give much better results.

'It is frequently necessary on blue-prints to represent additions in white, red, or yellow. A white line can easily be put on by using *chinese white* water-color. The best color for a red line on blue-prints is scarlet vermilion water-color; and for a yellow line none of the ordinary yellow water-colors gives as brilliant lines as Schoenfield & Co.'s *light chrome yellow.*

'For tinting drawings, water-colors and dilute inks are used. Effective tinting may be done on tracings by using colored pencils on the rough side of the linen.

'Electric Blue-printing

'The uncertainty of the sunlight for making prints has brought forward a printing frame in which an artificial light is used.

'One form of the electrical printing frame is an apparatus consisting of a hollow, glass cylinder, formed of two sections of glass

and resting on a circular base which is rotated by clockwork. An electric light is suspended in the centre line of the cylinder where it travels up and down by means of a clockwork attachment.

'The tracing and paper are wrapped around the outer surface of the glass where they are tightly held against the glass by a canvas which is wound around the cylinder by means of a vertical roller operated by a handwheel. The cylinder can be rotated at any desired speed and the light which travels up and down the axis of the cylinder can be moved through any desired distance or at any desired speed. These motions are all made automatically when the apparatus is once adjusted.

'In another type of electrical machine several horizontal rollers are provided, with the light so arranged that as the tracing and blue-print paper passes from one roller to another the exposure is made. The speed of the machine is controllable and the length of the tracing that can be printed is limited only by the length of the roll of blue-print paper. With this machine, then, long plans or profiles can be printed without the necessity of frequent splicing which is required with other types of printing frame; furthermore, the color of the print is also uniform throughout. The machine is driven by an electric motor. There are several machines of this general type on the market; some of them are provided with an apparatus for washing the prints as fast as they come from the machine.'

Overexposed Blue-prints. — Blue-prints which have been overexposed may be saved by washing them in a solution of $KCrO_4$ and rinsing thoroughly. By this treatment, the parts which have been exposed so that they appear green instead of blue will be brought back to a good blue.

To Write on Blue-prints. — Where it is desired to add white lines to a blue-print, one has the choice of using a heavy-bodied white wash to cover the blue, or a chemical eraser which removes the blue along the desired line. To remove the blue, a saturated solution of potassium oxalate may be used. The objection to the latter method is that the print must be thoroughly washed or the blue color will return in time.

If a saturated solution of sodium carbonate be used the white is permanent without washing. An ordinary blotter should be used to remove the excess of solution. As sodium carbonate is

always obtainable in either assay office or kitchen its use is probably more common than either potassium oxalate or a wash.

To Waterproof a Blue-print. — Blue-prints and paper drawings generally can be waterproofed by the use of refined paraffin. Saturate in melted paraffin pieces of absorbent cloth and cool. These can be used at any time subsequently. Spread a piece of the cloth on a smooth surface, superimpose on it the blue-print or drawing, and on top of this a second sheet of the cloth. Iron with a moderately hot iron. The paper will absorb paraffin from the cloths till saturated, more paraffin being put under the iron till thus affected. By this process the lines in the drawing are brought out and intensified. The paper is not shrunk or distorted and becomes translucent and waterproof. The advantage of waterproof blue-prints for use in the wet parts of mines is obvious.

Blue-print Solution.[1]— 'Make the following two solutions separately (in the light if desirable) and mix, *in subdued light or in a dark room*, equal parts of each of them:

Solution (1)

Citrate of Iron and Ammonia . . .	1 part	(by weight)
Water	5 parts	(by weight)

Solution (2)

Red Prussiate of Potash (recrystalized)	1 part	(by weight)
Water	5 parts	(by weight)

'The mixed solution is applied to the paper by means of a camel's-hair brush or a sponge; this is done in a dark room or in subdued light. The paper is coated by passing the sponge lightly over the surface three or four times, first lengthwise of the paper and then crosswise, giving the paper as dry a coating as possible consistent with having an even coating; it is then hung up to dry. The above coating will require about 5 minutes exposure in bright sunlight; for quick printing paper, use a larger proportion of citrate of iron and ammonia.

'*Blue-print Cloth.* — Blue-print cloth is prepared in the same manner as the blue-print paper. Its advantage over the paper lies solely in the fact that it does not shrink as badly and is much more durable. Prints which are to be used on construction work

[1] Breed & Hosmer.

where they are sure to get rough usage are sometimes made on cloth.

'*Tracing from a Blue-print.* — In making a tracing of another tracing it will be found that the lines can be more readily seen if a white paper is put under the lower tracing. It frequently happens that it is necessary to make a tracing of a blue-print. The white lines of the blue-print are not easily seen through the tracing linen. An arrangement which will assist greatly in such work is to have a piece of plate glass set into the top at one end of a drawing table in such a way that it forms part of the top of the table. The blue-print is placed over this glass and through the blue-print will make the white lines easily visible for copying.

'It is common practice, after a survey is made and before or during the computation of it, to plot the field notes accurately on detail paper and later to copy the plot on tracing cloth, which is the final drawing of the survey.

'From these tracing drawings any number of process prints can be made, the tracing taking the place of the negative used in photographic printing.

'*Tracing Cloths.* — For more permanent drawings a *tracing cloth* is used, made of a very uniform quality of linen coated with a preparation to render it transparent. Most tracing cloth, as it comes from the manufacturer, will not readily take the ink, and it is necessary to rub powdered chalk or talc powder over the entire surface of the cloth before inking the drawing. After the surface chalk is brushed off, the tracing cloth is ready for use. Tracing linen generally has one side glazed and the other dull. Pencil lines can be drawn on the rough side, but the smooth side will not take even a very soft pencil; either side may be used for ink drawings. Some draughtsmen prefer to use the glazed side but the dull side is more commonly used. A tracing inked on the glazed side may be tinted on the dull side either by crayons or by a wash; the latter will cockle the cloth unless it is put on quite "dry." It is easier to erase from the glazed than from the dull side, but the dull side will stand more erasing, and gives more uniform lines.

'Vandyke Prints

'Vandyke paper is a sensitized paper which is printed in the same way as a blue-print, except that the tracing is put into the

frame so that the ink lines will be against the Vandyke paper. The exposure is about five minutes in direct sunlight or, more definitely, until the portion of the Vandyke paper which protrudes beyond the tracing is a rich dark tan color. Fresh Vandyke paper is light yellow in color. The print is washed for about five minutes in clear water (where it grows lighter in color) and then it is put into a solution consisting of about one-half ounce of fixing salt (hyposulphite of soda) to one quart of water, where it turns dark brown. It is left in the fixing bath about five minutes, after which the print is again washed in water for twenty to thirty minutes and then hung up to dry. The fixing solution may be applied with a sponge or brush if only a few Vandykes are being made, but it is better to immerse them in a tank containing the solution.

'After the Vandyke print is washed the body is dark brown in color while the lines are white. This is not the final print to be sent out; it is simply the *negative*.

'This Vandyke print is then put into the printing-frame in place of the tracing, the *face* of the Vandyke being *next to* the sensitive side of the process paper, and from it as many prints as are desired are made on blue-print paper or on any kind of sensitized paper desired. These blue-prints made from Vandykes have a white background while the lines of the drawing appear in deep blue lines, for in this case the rays of the sun act only through the white parts of the Vandyke (the lines), whereas in making an ordinary blue-print from a tracing the sun's rays act on the paper through all parts of the tracing cloth *except* where the lines appear. Where brown lines on a white background are desired, the print is made by using a sensitized sheet of Vandyke paper, in place of the blue-print paper.

'One of the advantages of this process is that, as soon as a Vandyke has been made from the tracing, the tracing can be filed away and kept in excellent condition, the Vandyke being used in making all prints.

'Another advantage in the use of the blue-prints which have been made by this process is that any additions made in pencil or ink show clearly on the white background of the print, which is not true of the ordinary blue-print, on which corrections must be made with a bleaching fluid or water-color.'

Copying of Drawings

For Copying Drawings. — A method of copying drawings, which may be found of service, is given in the *Deutsches Baumgewerbes Blatt.* Any kind of opaque drawing paper in ordinary use may be employed for this purpose, stretched in the usual way over the drawing to be copied or traced. Then the paper is soaked with benzin by the aid of a cotton pad. The pad causes the benzin to enter the pores of the paper, rendering the latter more transparent than the finest tracing paper. The most delicate lines and tints show through the paper so treated, and may be copied with the greatest ease, for pencil, india ink, or water-colors take equally well on the benzinized surface. The paper is neither creased nor torn, remaining whole and supple. Indeed, pencil marks and water-color tinting last better upon paper treated in this way than on any other kind of tracing paper, the former being rather difficult to remove by rubber. When large drawings are to be dealt with the benzin treatment is only applied to parts at a time, thus keeping pace with the rapidity of advancement with the work. When the copy is completed the benzin rapidly evaporates, and the paper resumes its original and opaque appearance without betraying the faintest trace of the benzin. If it is desired to fix lead-pencil marks on ordinary drawing or tracing paper, this may be done by wetting it with milk and drying in the air.

X

BORE-HOLE SURVEYS

THE exploration of ground by means of the diamond drill has become very common. Companies working large bodies of mineral find that it pays to explore their ground thoroughly by bore-holes rather than by occasional drifts and cross-cuts. Coal companies now explore their beds of coal closely enough by means of bore-holes to be able to draw contour maps of the bottom of the bed and lay out their proposed workings by the contours. (See Fig. 76.)

By means of bore-holes, any faults which throw the coal beds are discovered. The diamond-drill hole is the common means used to tap water or gas in old workings. Where these old and abandoned workings are not carefully mapped, it is customary to keep bore-holes in advance of any workings which may be approaching them.

To keep the geological record of a bore-hole, the cores are labeled and boxed in order as they come from the hole. Pieces for assay are taken from them as desired. From these records it becomes an easy matter to draw the geological sections, and assay plans, of ground hundreds of feet from the nearest point to which man has access.

Bore-holes are frequently made to carry the discharge pipes from the pumps, for rope ways, and recently have been recommended for the purpose of carrying air to safety chambers in coal mines.[1]

When the core drill was first used, it was assumed that the hole traveled in a straight line, but it has been found that it does not. In many cases, the deviation is great. Mr. D. M. Sutor, of the Sullivan Machine Co., says that he found that all the holes drilled on the Rand showing marked deflection were drilled by one firm of contractors. They drilled a $2\frac{1}{8}'$ hole instead of the usual $2\frac{1}{16}'$ hole and used the common $1\frac{7}{8}'$ rods. Mr. Sutor also says that a horizontal hole will always climb, and that in cutting an angling contact, between different rocks, the drill will draw into the harder rock.

[1] Richard Lee, in *Engineering and Mining Journal*, January 12, 1907.

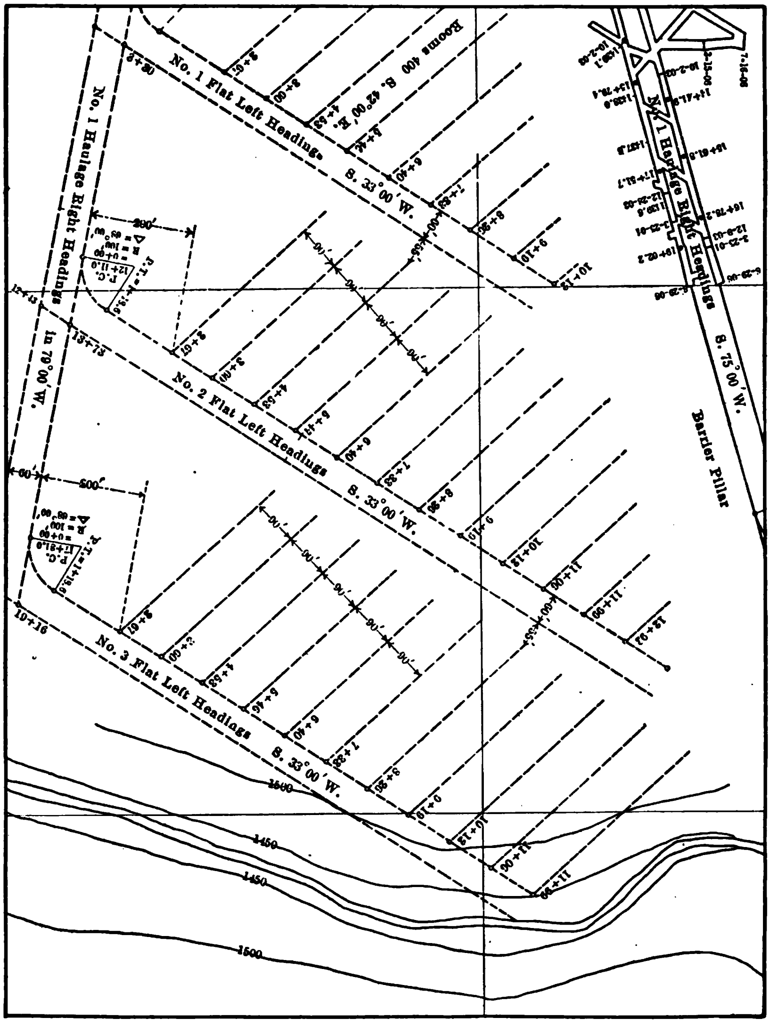


FIG. 76.—MAP OF PROPOSED WORKINGS.

One hole whose dip was 51° 30′ and whose length was 1090 feet, ended 280 feet from where it would had it been straight, and continued in the direction at which it was started.[1]

For short holes, where the deviation can only, at most, be a few inches, it is only necessary to measure the bearing and the angle of dip of the drill rods in order to map the hole corrected. But where long holes are bored, it becomes necessary to have some

[1] *Mines and Minerals*, vol. xii, p. 309.

means of determining the bearing and dip of the hole at any point along its whole length.

This has been accomplished in several ways. By one, a tube containing hydrofluoric acid is lowered and held at the point of observation until the acid etches the glass. By another, a tube containing liquid gelatin, upon which a magnetic needle floats, is lowered and allowed to congeal. Both these methods are only partially satisfactory. W. Helme, of Johannesburg, has invented and described an apparatus which is reported to do excellent work. The following description is by Mr. Helme.

'An Instrument for Surveying Bore-holes [1]

'The instrument comprises a brass cylinder 20 to 30 inches long; both length and diameter are varied to suit the particular requirements. The cylinder is made in two portions, which screw together, quite flush, shoulder to shoulder. The top and bottom are closed by means of tightly fitting screwed plugs. To the top plug is attached a brass swivel with an eyepiece, by which the instrument is suspended. The swivel is fitted to the plug with ball bearings. The object of this swivel is to prevent the wire, which is used in lowering the instrument, from twisting; also to minimized risk of the instrument "kicking" against the sides of the bore-hole when being lowered or raised. Inside the cylinder, immediately beneath the top plug, is a spring resting on a pad, which keeps firmly in position a small watch or timepiece. Below the watch is a dry battery. Below this again is arranged a tiny electric lamp, and below the lamp is a glass plate from the centre of which hangs a small plumb-bob. Below the plumb-bob is a circular brass plate supported on gimbal bearings, so that it always remains in a horizontal position. On this plate is placed a small disc of sensitized paper. Below this is another electric lamp and below this again is a compass, which is also supported on gimbal bearings.

'On the dial plate of the compass is placed another disc of sensitized paper; each disc is pierced by a pin-prick in the centre and another on one side, and both discs are fixed in exactly the same relative position, one above the other when in the instrument. The whole is kept firmly in position from below by another spring placed under the little cup holding the magnetic needle, and

[1] A paper read before The Institute of Mine Surveyors, Johannesburg.

resting on the bottom screwed plug. When the hand of the watch is passing the 12 o'clock point on the dial, it makes contact for about fifteen seconds with a small projecting spring made of copper foil which is connected with one line from the battery. The hand of the watch is connected with the other line, and so, when in contact with the spring the circuit is completed, the electric lamps are lighted, and photographs are taken of the positions of the plumb-bob and the magnetic needle.

It is only necessary to set the watch so that the hand will only pass the 12 o'clock point after sufficient time has elapsed to allow for the instrument being lowered to that depth, and also to allow for the plumb-bob and magnetic needle having come to rest. In practice it is usual to take readings at say every 200 to 300 feet, and two readings should invariably be taken in each instance. When once the photographs have been obtained, the rest of the work is easy; for, the height of the point of suspension of the plumb-bob above the centre of the disc being known, and the distance of the lower end of the plumb-bob from the centre of the disc having been obtained, by accurately measuring the distance between the centre of the photograph of the plumb-bob and the centre of the disc, the angle of dip can be calculated. The direction is also easily obtained by placing the two discs in the same relative positions which they occupied while in the instrument, which can at once be done by means of the two pin-pricks on each. The direction of the line joining the centre with the image of the plumb-bob on the one disc will then (unless it happens to fall in the magnetic meridian) make an angle with the photograph of the magnetic needle on the other disc, and from this angle the magnetic direction of the path of the bore-hole at that particular point is determined.

'In surveying a bore-hole, say, 4000 feet in length, two sets of readings should first be obtained at regular intervals, which should not exceed 250 feet in length. When these have been obtained, the dip and deviation must be calculated for each point; and then sufficient data is [are] available to plot in plan and section, the true path taken by the bore-hole.'

An apparatus for photographing the sides of the bore-hole is described in the *Engineering and Mining Journal*, May 18, 1907. This is electrically operated and takes fifty pictures each $3\frac{5}{8} \times 1\frac{1}{4}$ inches, to one loading.

Bibliography: *Bore-hole Surveys*. — Bore-holes, *Eng. and Min. Jour.*, vol. lxxxiii, p. 94; Survey of Diamond-drill Bore-holes, 'Rep. Chamber of Mines,' W. A., August, 1903; The Diamond-drill Clinometer, *Mining Journal*, vol. liii, 1905; A Device for Bore-hole Survey, *Page's Weekly*, February 17, 1905; Bore-hole Surveying, Foster's 'Ore and Stone Mining'; An Instrument for Survey of Bore-holes, *Mining Reporter*, vol. liii, p. 64; Bore-hole Survey, *ibid.*, March 9, 1905; Photograph of Bore-hole Walls, *Eng. and Min. Jour.*, May 18, 1907.

Photography as an Aid to the Engineer

Every engineer knows of the uses to which the camera is now put in topographic work, not only to give a picture of the surface configurations, but, by triangulation methods, to locate points of the topography by course and bearing. One who wishes a detailed knowledge of the topographic methods is referred to 'Transactions Society of Engineers,' 1899, p. 171, or to Trans. A. I. M. E., Vol. XX, p. 740.

The examining engineer has a multitude of uses for his camera, and it is as much a part of his equipment as is his transit. H. O. Packer[1] says: 'The mining engineer is behind the times if he does not photograph all the principal faces of ore and also the timbering underground and the mill, outcrop, natural streams of water, etc., above ground. In each photograph there should be some object, as a man or a shovel, to make comparisons by, so that those who see the photo can judge of the size of the seams, veins, etc., represented. Distant views should be taken when possible, to show the general topography of the claim.'

One has only to pick up any mining journal and examine its pages to see how generally the camera is used. A more extended use of it underground has undoubtedly been delayed by the inadequacy of ordinary flashlight apparatus. When using the ordinary pistol flashlight, it is best to give two or more flashes for each exposure with the pistol held in different positions. By this method, the shadows are softened.

The author has used with success a flash-lamp which blows powdered magnesium into an alcohol flame. The size of the flame and the length of time of the flash is determined by the lung

[1] 'How Mines Should be Examined,' *Engineering and Mining Journal*.

capacity of the man who blows the flash. To make sharp contrast between different geological formations apparent, it is frequently necessary to chalk the surface of one before taking the photo.

But the services of the camera are not limited to underground operations even so far as the surveyor is concerned.

Some of our large mines now use a large camera (The Tamarack Mining Company of Michigan uses plates 20″ × 24″) to photograph their working map periodically, The photograph then serves the same purpose as the tracing and blue-print method does in keeping the general office, directors, etc., informed of the operations underground. This photograph serves admirably where it is desired to have zinc etchings of the map made for general distribution.

A miniature camera has been successfully used to photograph the interior of bore-holes. We have in this way pictures of the rocks which lie hundreds of feet distant from the nearest point which man can reach.

Although the camera is already extensively used, it is reasonable to predict that there are many other uses to which the mining engineer can put it. Fortunately, nowadays, very few men escape the camera fever at some stage of their young manhood, and the engineer, at least, should be rather more than an amateur in the use of this valuable companion.

Bibliography: Photographic Surveying. — 'Photography Applied to Surveying,' Lieut. H. A. Reed, N. Y., 1888; 'Photographic Surveying,' E. Deville, Ottawa, 1895; 'Photo-Survey Instruments,' J. Brodges Lee, *Trans. Soc. of Eng.*, 1899, p. 171; 'Photo-Survey in Arizona,' *Trans. A. I. M. E.*, vol. xx, p. 740.

XI

METHODS OF VARIOUS ENGINEERS

Mr. Lucien Eaton, superintendent of Iron Belt Mine, Iron Belt, Wis., furnishes the following detailed description of surveying methods used by him in the iron mines:

'Following is a description of the equipment and some of the methods of mine surveying and office-work which I have used in my work for a large iron-mining company.

'*Equipment: Transits.* — Transits used have been all of C. L. Berger's make, either number 6 or number 6d, with interchangeable side and top telescope, reflecting prism and short-focus lens, and full vertical circle with guard. Both vertical and horizontal circles are 5 inches in diameter, graduated to minutes on solid silver. The horizontal circle is graduated both ways, from left to right and from right to left, from 0° to 360°. The number 6 transit has a compass-box and the number *6d* has none, having instead the U-frame. The latter is by far the more satisfactory instrument. All transits have inverting images, fixed stadia wires and diagonal as well as vertical and horizontal cross-hairs. The tripods have extension legs. Half-length tripods are often used in raises and small shafts, but these have not been found absolutely necessary.

'*Levels.* — In surface work a 20-inch Y-level or precision-level is used. Underground all levels are run with the level-bubble on the transit.

'*Rods.* — Slight-rods on surface are made of $\frac{3}{8}$-inch steel, about 4 feet long. Level-rods are Philadelphia style, 7 feet long when closed and 13 feet long when extended, for surface work, and 5 feet long when closed and 9 feet long when extended, for underground work. Folding steel rods have been tried, but have been found unsatisfactory.

'*Plumb-bobs.* — Plumb-bobs are of brass, either 6 or 8 ounces in weight, either regular or long pattern. In shaft work 9-pound square, lead weights are used on plumbing-wires.

'Braided cotton fish-line, about $\frac{1}{32}$-inch in diameter, in 7-foot lengths, is used for plumb-bob strings.

'For plumbing short-lifts, up to 150 feet, number 30 tinned iron wire put up in 50-foot spools, is used. For longer distances, number 22 soft copper wire in 1-pound-spools is used. If weights heavier than 9 pounds are used, the wire must be of hard copper or of larger diameter.

'*Tapes.* — For ordinary work, a 150-foot steel tape is used, $\frac{1}{4}$ inch wide, graduated to tenths and hundredths of a foot. It is wound on a four-arm, open nickel-plated, brass reel, with folding handle on one side and strap on the other. A 200-foot reel is used with a 150-foot tape to allow for the crowding of the tape by dirt and mud.

'For distances over 150 feet, a 300-foot tape, graduated to feet, with each foot-number stamped on, is used, fractions of a foot being measured with a 6-inch wooden scale, graduated on one side from 0 to 50/100 and on the other from 50/100 to 100/100 of a foot. The front end of this tape has a snap-handle or strap-loop, and the graduation begins 6 inches from the end. In measuring the tape is held, at the next foot-mark greater than the distance to be measured, by a steel clip that is provided with a screw-clamp. This gives a good handle, adjustable to any part of the tape. The 300-foot tapes are bought from the Chicago Steel Tape Co., and are warranted against breakage. They are a little heavier than most other tapes, but their weight is their only drawback.

'*Bags, etc.* — In underground work, the foresight carries a small leather bag, in which are kept nails, plumb-bobs, hammer, centre-punch and the 150-foot tape. This bag is 8 inches wide, 8 inches deep, and 2 inches thick, with flap-cover and a 1-inch shoulder-strap. For stations, or 'points,' number 8 horseshoe nails are used, the heads being flattened and drilled with a $\frac{1}{8}$-inch hole. If the holes are punched in the nails, they have to be reamed out afterwards to avoid cutting the strings. A small centre-punch is always included in the outfit.

'For surface work, a larger bag for holding stakes, is carried, which has small pockets outside for tacks and for blumb-bobs, tape-clamp, and centre-punch.

'*Stations.* — Stations consist of horseshoe nails as above described, driven into timbers or into plugs, which have been driven

into holes drilled in the back, or they are punch-marks on the rail, marked additionally by three holes punched in the outer side of the rail. These are usually set near joints or over ties. An excellent temporary point is a horseshoe nail driven into a tie up to the head, the head being then bent over flat on the wood. The hole in the head of the nail is the station.

'*Men: Foresight.* — The foresight carries the bag with the tape, plumb-bob, nails, hammer, and centre-punch, with him all the time. His duties are to drive nails or make punch-marks for stations, to hang up the plumb-bob and hold his candle for sights ahead, to hold the front end of the tape in measuring, and to hold his light for sights in taking side notes. His is the responsibility of putting the new stations in the right place, and upon him depends to a great extent the rapidity of the work.

'*Transit Man.* — The transit man is usually the head of the party. He carries the transit at all times, and is responsible for its safety. He reads all angles and takes all notes, and oversees all measurements between stations.

'*Backsight.* — The backsight holds his light for backsights, measures all distances, and carries the tripod or empty transit-box.

'Surveying Methods

'*Underground Work: Plane Surveying.* — The method of procedure is as follows: In entering or approaching a working place which is to be surveyed, the two nearest existing stations are found, and the distance between them accurately measured. If neither station appears to have moved and the distance agrees with that measured when the stations were originally set (a check of 0.01 to 0.03 is considered practical agreement), the transit is set up under the head point — or over it if it be in the rail — the foresight puts in the head point, and the angle is read. The plumb-bobs are hung up by merely passing the end of the string through the hold in the nail, and tying it round the standing part of the string again, with a loop and slip-knot. This is easily moved up or down, or taken down. In giving sight at the string, the candle should be held horizontally behind the string and shielded with the hand. Except in sights over 150 feet long this gives sufficient light. In long sights, two or more candles are used.

'The transit is set with the vernier of the horizontal circle at zero, and all angles are read to the right, to the nearest 30″, and are doubled for check, the actual reading of the vernier being recorded. The multiplication necessary to see if the angle has been properly read is made mentally before the transit is moved. All readings of the vernier are made with a magnifying glass, except those for side notes. When the angle has been read twice, the backsight takes down his plumb-bob, gives it to the foresight, takes the reel-end of the tape and measures the distance to the new point. Practically all measurements are made from the transit-head horizontally, and read twice as a check. If the new point is in the rail, the vertical angle is read, and the horizontal distance is calculated in the office.

'The form of notes used is as follows:

August 24, 1906. { M. H. B. / E. C. W. / L. E.

Third Level			No. 5 Contract		Description.
Sta.	Azimuth	Vert. Angle	Dist.	New Sta.	
		B. S.	39.84		
At 309	187° 38′		114.93	310	Centre
On 308	14° 56′				
At 310	272° 18′ 30″	−4° 27′	35.26	311	Right Rail
On 309	184° 37′				R 3 R Rib

'These notes are kept on the left-hand page of the note-book.

'If, when the new station has been set, further measurements are necessary to define the sides of the drift or stope, these are taken, if possible, by offsets to left or right from the line of the traverse, and are recorded just under the new station's number and description, thus:

At 310	272° 18′ 30″	−4° 27′	35.26	311	Right Rail
On 309	184° 37′				R 3 R Rib
				+20′ L 2	L Rib & R 5 R Rib
				+28′ R 8	Corner & L 5 L Rib

'This would represent the notes for a drift opening into a stope, thus (Fig. 77):

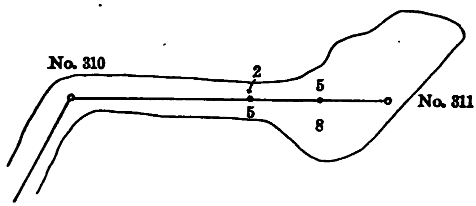


FIG. 77.—SURVEY LINE TO STOPE.

'In order to survey the end of the stope, the transit is set up at 311, and, with the vernier at zero, one sight is taken on 310. The foresight then holds his light and measures to the controlling points of the stope, calling out the description at each reading; for example, "Left Rib, Left Corner, Left Corner of Breast," etc. The transit man reads angles to these points to the nearest 15 minutes for distance up to 100 feet, and to the nearest 5 minutes for longer distances. These notes are kept on the right-hand page, thus:

'THIRD LEVEL NO. 5 CONTRACT

At 311 on 310 B. S. = 35.26

1	100° 15′	11′	L. R. (Left Rib)
2	132° 00	21	L. Cor. Bst. (Left Corner of Breast)
3	168° 30	21	R. Cor. Bst. (Right Corner of Breast)

'In complicated openings a sketch is also made approximately to scale, and the readings are plotted by eye and numbered on it. Readings are usually taken waist high, and if much higher, have the vertical angle read.

'In mines where the working places are scattered, and one or two set-ups are made at each place, from 25 to 30 set-ups are considered a good day's work; but on straight surveys 32 set-ups have been made, with side notes, in four hours, and 29 set-ups, including running up 5 raises and carrying elevations, in 5½ hours.

'*Surveying through Inclined Shafts and Raises.* — In shaft- and raise-work, the duties of the different members of the party are the same as in surveying on the levels, except that the transit man usually does the measuring. Points are set in the hanging, when

possible, and the transit is set up underneath. In running up a raise or shaft, it is usually necessary to use the reflecting prism on the eyepiece of the transit. The transit is set up under the point of the foot of the raise, or in the shaft, and the azimuth read as in plane surveying, except that the centre cross-hairs are set on the top of a little blob of candle-grease, which is pressed on the plumb-bob string at the foresight. The vertical angle is read each time the horizontal angle is read, and both readings must agree. Measurement is made from the transit-head to the grease along the line of sight. In order to carry elevations, the following distances are measured: Nail to transit-head, and transit-head to floor, and nail to grease at foresight and grease to floor. It has been found usually most satisfactory to carry the elevations from the nails used as stations, instead of from the rails, though neither method is perfect.

'In steep sights down and sometimes in sights upward, it is necessary to use the auxiliary telescope. This is usually used as a top telescope and is ranged into line with the main telescope by setting the centre cross-hair of the main telescope on a plumb-bob string at about the same elevation, and then, by means of the tangent-screws on the base of the top telescope, ranging that telescope into line so that the centre cross-hair coincides with the same plumb-bob string. If in surveying downward, the sight ahead must be made with the top telescope, the fact that it was used is recorded under the vertical angle, or, if the angle is not so steep as to require the top telescope for the backsight from the point ahead, the reading of the vertical angle and measurement may be postponed till the next set-up, and be performed when taking the backsight. In either case the use of the top telescope when measuring is mentioned in the notes. In measuring when the top telescope is used, the measurement is taken from the transit-head, just as if the top telescope were not in use, and a correction is made in the vertical angle afterwards in the office, before calculating the vertical and horizontal distances. This correction is made as follows: The distance from the line of collimation of the top telescope to that of the main telescope is, in our instruments, 0.30 of a foot. The distance measured is divided by 0.30, the quotient being the natural cotangent of the angle of correction. This angle is then looked up in the tables, and is added to the vertical angle as read, if the sight is upward, and

subtracted from it, if the sight is downward. An example of the notes of such a survey follows:

At 408	272° 12′	−63° 19′	29.42	48*a*	Centre of
On 407	184° 24′	−63° 19′			ladder-road

Top telescope

At 408, Inst. to nail = 3.57. H.I. = + 4.20 at 48*a*. Nail to grease = −2.15. Grease to floor = −4.90

'All vertical angles and measurements are marked + or −, the plus sign indicating measurement upward, the minus sign downward.

'Theoretically, the more accurate method of measuring steep inclined distances, when running a survey down a shaft or winze, is to measure and read the vertical angle back from the head-point, when taking backsight up the shaft, thus doing away with any error due to lack of parallelism between the top and main telescopes; but I have tried both methods between the same two points, and there has been no difference in the calculated horizontal distances after correction has been made for the use of the top telescope. Measuring on the backsight is a nuisance with inexperienced helpers, and entails this danger, that the backsight has to read the tape and is likely to make an error, if there is no one to watch him.

'The side telescope is seldom used. When it is used, a nail is set 0.30 of a foot on each side of the real foresight, and the horizontal angles are read first with the transit in normal position and again plunged, the mean of the two angles being taken as correct. No correction is necessary in the vertical angle if the side telescope has been made parallel with the main telescope.

'*Plumbing Vertical Shafts.* — In plumbing a vertical shaft or winze, the survey is carried to a point set in such a position that two wires can be lined in from it with one sight and can hang down the shaft without striking any obstruction. A scaffold is usually built over the shaft, with a piece of plank in line with, and over, the positions which the two wires are to occupy. A nail is now driven up into the plank in the position proper for the wire farthest from the transit. This wire is now let down to the level to which the survey is to be made, the upper end is fastened to the nail, and a 9-pound weight is attached to the lower end. This weight is now brought to rest in a pail of water, the surface of the water being

protected from falling drops by pieces of candle- or powder-boxes or other small boards.

'The cross-hairs of the transit are now set on this wire, and another nail is driven up and a wire suspended from it, as in the case of the first wire, the second wire being hung exactly in the line of sight between the transit and the first wire. The angle is now read to the near wire, and measurement is made as in the case of any station on a level, and the distance between the two wires is also measured. The transit is now carried down to the level below and is set up as nearly on line with the two wires in the shaft as is possible with the naked eye, final adjustment being made by means of the adjustable legs and sliding head. The distance between the wires is measured, and must check with that measured at the upper level.

'With the vernier at zero and the cross-hairs set on either of the wires, the azimuth is read to the new station and the distances measured both ahead and back to the near wire, care being taken to record which wire was used. Before moving the transit, it is necessary to preserve the line of sight to the head point, as there is no point set where the transit stands. In a timbered drift, a nail is set on line in one of the caps, and is used as backsight at the next set-up. In rock drifts, usually a heavy piece of timber or a tripod-weight is put under the transit, and a temporary mark is made under the centre of the vertical axis, as shown by the point of a plumb-bob hung underneath.

'In carrying a survey up a vertical raise or shaft, the operation is the same, the points on the upper level being temporarily disconnected with the rest of the survey, and the calculation is reversed when they have been tied in to known points on the lower level.

'The method of connecting surface and underground surveys by means of single wires in two connected vertical shafts is often used.

'*Lining-in Timber in Inclined Shafts.* — Too little importance is usually attached to the straightness of inclined shafts, the alignment of the sets being intrusted to the timber-boss. Inaccuracies are frequent, and the errors are usually cumulative. In order to eliminate error, the use of a transit at frequent intervals is necessary. The method used in one large shaft was as follows: The shaft is inclined 60° from the horizontal in direction North 14° 50′

West. The alignment work was done in the cage compartment at the west end of the shaft. Bearers were, of course, set very carefully on surface in the right direction, and the sets were hung below them. On the collar-set a nail was driven into the upper edge of the foot-wall-plate 10 inches west of the joggle cut for the dividing. The transit was set up over this, and the vertical height to the horizontal axis was measured. A nail was then driven into the hanging-wall-plate of the collar-set and into each wall-plate of the sets below, exactly 10″ west of the joggle. The sets were then wedged over, till all the nails were in the same vertical plane, the bearing of which was North 14° 50′ West. In determining the inclination of the sets, the telescope of the transit was set at 60° downward from the horizontal, and the distance of this line of sight from the foot-wall-plates was calculated from the vertical height of instrument already measured. The target on a Philadelphia level-rod was now set at the calculated distance, and, with the rod resting with its foot on the inside face of the foot-wall-plate and the upper end on the hanging-wall-plate (thus being at right angles with the line of sight but in the same vertical plane) the sets were wedged toward foot or hanging till the target came into line with the middle horizontal cross-hair of the telescope. The corners were then tested with a square and the foot-wall-plates with a hand level, and the nails were checked again for line with the transit. After one or two sets have been lined-in in this way, the distance from the foot-wall-plate to the line of sight need not be calculated, but instead the target can be set directly, a known shaft-set being used as bench-mark.

'Another method of aligning all the sets for elevation eliminates the use of the level-rod. Strings are stretched between the nails in foot- and hanging-wall-plates, and little blobs of grease are pressed on the strings at the calculated height above the foot-wall-plate. When the strings all coincide with the vertical cross-hair of the transit and the blobs of grease all show at the centre of the cross-hairs, the sets are all in line and at the proper elevation. This method is not so simple in operation as that previously described, since the strings are bothersome to handle and are very confusing, if more than one are in use at the same time.

'Before the shaft-sets were finally lined in with the transit, two or three sets at a time would be left loose in the blocking, so that they could be easily moved into their exact position, when the

engineer came around. It takes little more time to line in three sets than one, about on hour and a half being necessary for three sets, with a good shaft crew. When the shaft is down about ten sets below the transit, it is not necessary to line in every set, but all should be tested after they are blocked. With a good timber-boss in charge of the shaft-work, it is enough to line in one set in every 20 feet.

'*Sketching.* — In mines where the caving system is used, after the ore has been blocked out, much surveying can be eliminated by direct measurement from raises, corners, etc., and by plotting on blue-prints. These blue-prints are made every month for every mine, and show each level and sub-level separately. When necessary, the transit stations 'points' are shown on them, with their numbers and the distances between them. This is a great help in finding points and prevents many errors. Where a transit survey is not feasible, short drifts and cross-cuts are located by a compass survey with a Brunton transit, and are sketched directly with the notes of the survey on the blue-print. In large sub-levels, where the ground is crushing badly and it is impossible to 'hold points,' it would be practically impossible to keep the different contracts properly surveyed without the use of blue-prints. In rock drifting they are practically valueless.

'*Note-books.* — "Eugene Dietgen Co.'s Field-book," No. 401, is the type of field-book used both for surface and underground work, and has been found to be very satisfactory. Surface and underground work are always kept in separate books, and each mine has its own set of books, which are not used at any other mine.

'*Calculation.* — All calculation is done in books, bound in cloth, with 250 ruled and numbered pages, each 8 × 10 inches, of good paper. The calculations for each mine are kept separate, each mine having a set of books. When a great deal of surface work is being done at a mine, the surface calculations are kept in a separate book from the underground calculations.

'All calculation is done in duplicate, preferably by two men working together, and the notes are kept in ink. R. L. Gurden's "Traverse Tables," and Bruhn's "Seven Place Logarithms" are used. All surveying that is done with the transit is calculated for coördinates, using some arbitrary point, preferably a section corner, as origin. Courses are calculated from true north, which

is either assumed to coincide with a section line or is determined by an observation on the sun or Polaris. If the new work is tied-in to old known points, reference is made to the book and page where the data can be found, and the data are copied into the new book, or at the new page, as well. Reference is also made to the number and page of the field-book, and the date and the initials of the transit man are entered. Full descriptions of permanent points are entered in a special part of the calculation-book.

'Calculations of the notes already used would be as follows:

	THIRD LEVEL		NO. 5 CONTRACT		
	Data see No. 1, p. 112.		309 = S. 1325.82	1645.12 W.	
August 24, 1906.	L. E.	F. B. No. 1, p. 64.	308–309 = S. 01° 27′ W.		
At 309 on 308	310		98.7915	15.4998	
187° 28′	114.93		13.8308	2.1700	
S. 08° 55′ W.			0.9188	0.1441	
			113.5411 S.	17.8139 W.	
		310 =	1439.36 S.	1162.93 W.	
At 310 on 309			311	6.8082	34.3315
272° 16′	−4° 27′	for 35.26	35.15	0.0292	0.1471
N. 78° 47′ W.	34.8945			6.8374 N.	34.4786 W.
	0.2592				
	35.1537		311 =	1432.52 S.	1697.41 W.

'In calculations of a survey where a top telescope was used, or where elevations are carried by means of the vertical angle, both the vertical and horizontal distances are calculated, instead of only the horizontal distance, as above in the calculations of number 311.

'*Mapping.* — The instruments used in mapping are as follows:

(1) A 5-foot steel straight-edge.

(2) Two 8-inch German silver triangles, one 45°, and one 30° × 60°.

(3) An 8-inch German silver protractor, with horn-centre and beveled edges, but without any arm. It is graduated to quarter degrees from 0° to 360° from left to right and from right to left, to correspond with the horizontal circle of the transit. Such a protractor can be procured by special order

for $13. It is vastly superior in speed and convenience to a protractor with an arm, and is just as accurate.

(4) A 12-inch German silver flat scale with beveled edges, graduated to 50ths of an inch on both edges, the graduations starting on both sides from the same end. It has a small handle in the centre for convenience in moving. The graduations begin ¼-inch from each end. Such a scale can be obtained by special order for $3.

(5) A 12-inch flat, box-wood scale, with white enameled edges, graduated to 20ths and 40ths of an inch.

(6) A number 10 needle, with the eye end set in a piece of old eraser. This is for a pricker.

(7) A 4½-inch aluminum handled, right-line pen.

(8) A 'Union' eraser for pencil and ink, and Kohinoor pencils, 6H and 8H.

(9) India and colored inks.

(10) Several 3-pound canvas or leather shot-bags, to be used for weights.

'For making maps, "Extra Heavy Paragon Egg-shell Paper," mounted on muslin and thoroughly dried, is used. This is obtained in 10-yard rolls, 58½ inches wide. It is superior to any brand I know. Cheap paper is very expensive in the long run. For making tracings "Imperial Tracing Cloth" is very good.

'All underground maps are plotted on a scale of 50 feet to the inch, and are laid off in 4-inch squares, i.e., 200 feet to the square, and have titles and borders. The coördinates of the sides of the squares are printed on the maps at the bottom or the right-hand end of the lines. The title is usually put at the top and is in plain Roman letters.

'Each map shows one level in black and sub-levels above it, not too large, in colors, according to elevation. All elevations are calculated from the same bench-mark, and are shown on the map in the same color as the level or sub-level to which they belong. When sub-levels are large, they have individual maps, and are plotted in black, with the main level below them dotted in black.

'Vertical cross- and longitudinal-sections or projections are made at whatever intervals are thought best, and are usually, in

large mines, made to cut the ore-body in an east-and-west or north-and-south plane. They always represent the view looking east or north.

'Points are plotted by coördinates from the near sides of the square in which they lie, and are represented by needle-pricks, enclosed in a small circle drawn with the pencil. In plotting side notes, the protractor is placed over the point at which the transit was set up, and the 0° line is turned to the point of backsight. The angles are turned off on the edge and marked by small dashes, and numbered, and the distances are afterwards plotted to correspond to the numbering of the angles. Where timber was used in the mine, the edges of the workings are drawn in with a straight-edge; if no timber was required, the lines are drawn free-hand. Stopes running above the level are shown dotted. Floors mined are "flat-tinted" in gray on the map and cross-hatched in the tracings.

'The mines are surveyed every month and the extensions are plotted, or "posted." In posting the tracings — i.e., in adding the extensions of the last month — the tracings are matched over the maps by means of the coördinate squares, and are held in place by shot-bags. Thumb-tacks are never used, as they injure the maps.

'Blue-prints are made every month from the tracings, and the last month's extensions are colored red with water-color paint or with ink, and the contract numbers are written on the print with a 10 per cent. solution of oxalate of potassium.

'Surface maps are made in two scales, 50 feet to the inch and 200 feet to the inch. In rare cases the scale may be as small as 400 feet to the inch. Fifty-foot scale maps are made 35×58 inches, and represent 80 acres of land, two "forties," being longer east and west. Two hundred-foot scale maps are made 35×35 inches or 35×58 inches, and represent one or two square miles. Standard symbols are used, where necessary, as in "Smith's Topographical Drawing."'

Union Pacific Coal Co.[1]

Superior Mine. — Meridian is determined by direct solar observation and checked by Polaris. Where meridian is carried down a shaft, it is generally done by establishing three points in a

[1] Description furnished by Frank A. Manly, superintendent.

vertical plane at top of shaft, placing transit in this vertical plane leaning over shaft, and reëstablishing the plane at shaft bottom by means of telescope revolving in the vertical plane. While doing this, the plate is not level. By this means no auxiliary telescope is needed. Stations are marked by three notches and sometimes by a circle of white lead. Set-up is made over point carried to floor.

A continuous vernier is carried from the meridian.

All notes are in the form of sketches. One hundred-foot steel tapes are used. Maps to scale of 100, 200, 400, and 600 feet to an inch are made upon all sizes of paper. All mapping is done by means of latitudes and departures. Blue-prints and photographs of the maps are made whenever needed.

Calumet & Hecla [1]

The party consists of four men: transit man, front and rear chainmen, and rear rodman. Meridian is determined by observation on eastern elongation of Polaris and carried underground by transit traverse through two inclined shafts. In sinking vertical shaft, two wires (B and S 22, piano wire) in diagonally opposite corners, are used to keep shaft plumb. Two wires also are used to carry line down. Azimuth is found underground by stretching a wire so that it just touches each. Eleven-pound iron bobs are used to stretch plumb-wire. The stations used are spads in wooden plug or a nail set in cross-tie of a level. The station is numbered by the number of the level, the number of station upon that level, and whether north or south of base-line shaft.

The instrument is set up over a point carried to the floor.

Side notes are recorded on sketch on right-hand page of note-book. Measurements taken horizontally on floor of levels, along rail of incline shafts. Tape used is 125 feet in length.

Maps are 50, 150, or 400 feet to the inch, and are of various sizes. All platting is done by coördinates. Extensions are shown by tinting blue-prints of map. Blue-prints are taken monthly, and photographs occasionally. A copy of the regular map is tinted to show the quality of ore in various openings.

Bore-holes are tested for degree of dip by means of hydrofluoric acid in glass tubes.

[1] Practice as described by E. S. Grierson, chief engineer.

Poorman[1]

At the properties of the Poorman Gold Mines, Ltd., Silver City, Idaho, the party consists of two men. The meridian is obtained by pole-star observations and is carried underground by traverse.

The stations are screw-hooks (*m*, Fig. 46), set in plugs or caps or stulls, and marked by a brass tag 1½ inches square, nailed to timber or plug. Sometimes the number is scribed in the timber in Roman numerals. Each opening has its own series of numbers from 1 to *n*.

The set-up is always made under the plumb-bob. For sights at short distance, the front side of the plumb-bob string is illuminated — the cross-hairs then show plainly against the string. For long sights, two candles held together behind the string are used as a target.

Angles are read both left and right, always doubled, and the doubled reading also recorded. Check by needle reading.

Form of Notes

Sta.	Angle	Distance	Needle	True Bearing	Remarks
3–4	4–12 R. 2° 06′	45.63	N. 32° 15′ E.	N. 48° 27′ E.	
4–5	7–52 L. 3° 56′	16.40	N. 28° 15′ E.	N. 44° 31′ E.	

Fifty- and one-hundred-foot tapes are used. All tape readings are made twice to check. Maps are to scale of 1 = 1000 and platting is done by coördinates. No blue-prints or photographs are made.

Stopes are measured up roughly each month, but accurate measurements are rarely needed.

Copper Queen

The surveying practice of The Copper Queen Consolidated Mining Company is outlined by W. G. McBride, of that company.

[1] Data furnished by R. H. Britt, manager.

The surveying party consists of transit man and chainman. The meridian is secured from a triangulation line of the United States Geological Survey's topographic survey, and is carried underground by one wire in each of two shafts, or by two wires in one shaft. Number seven steel piano wire is used for this purpose. A plumb-bob of 41 pounds weight is used.

The stations are spads driven into timber or plug in rock hole. The stations are numbered by means of attached copper tags, the numbers running from number one consecutively, upon each level, as the stations are put in. No numbers are duplicated. All set-ups are made under the station. For target, the plumb-bob line is illuminated by candle through ground glass. Angles are all turned to right from zero on backsight, and doubled for check.

One-hundred-foot tapes are used underground, and three-hundred-foot tapes on the surface. Measurements are made on the horizontal or on the incline and the vertical angle read.

The maps are made to the scale of one inch to fifty feet, paper 22 × 9 feet held upon rollers. All angles are plotted upon by means of latitude and departure. Blue-prints are taken monthly.

Special stope-books of section-paper are used, the stopes being all timbered by square sets, the chute is used as a reference point, and the outlines of the stope sketched.

The assay maps are tracings from the regular mine map.

Portland Mine of Cripple Creek [1]

With the Portland Gold Mining Company the surveying party consists of two men. Meridian is taken by direct sun observation, and carried down a vertical shaft by means of two wires. Number 20 copper wire and 7½-pound cast-iron window weights, suspended in oil or water, are used. The meridian is taken off the wires at each level by setting the transit up in the plane of the two wires.

For stations, bored horseshoe nails (*g*, Fig. 46) are set in wooden plugs driven into half-inch drill-holes. The stations are marked by means of numbered zinc tags, and the tags are put in consecutively. In this way, station number 1200 may be on the

[1] Data furnished by Mr. Howard Spangler, chief engineer.

third level, and station number 1201 on the eighteenth level. To find the position of any station by number, it is necessary to look that station number up in the index.

The instrument is always set up under the plumb-bob. Sight is taken at the top of the plumb-bob, which is illuminated by candle behind a piece of tracing cloth held smooth in a frame. Angles are all turned to the right from zero at backsight, and doubled.

FORM OF NOTES

At Sta.	Angle Turned	True Course (calculated)	Mag. Bearing	Vert. Angle	Measured Distance	Horiz. Dist.	Vert. Dist.	Obj. Sighted	Remarks

The offset measurements are recorded below the notes of the course as follows: 27 $\frac{2.40}{3.60}$ and extended, read, at 27 feet from the instrument, the measurement from the stretched tape to the left side of the drift is 2.40 feet, to the right, 3.60 feet. Both top and side telescopes are used. The tape is 200 feet long, graduated to hundredths.

Maps to the scale of 1 inch to 30 feet are made upon paper 5×9 feet. All plotting is done by coördinates. No blue-prints or photographs of the map are made.

A mine model, made of sheets of glass to represent each level with workings drawn in ink, is in constant use by the engineer, the foreman, and the superintendent. The engineer, speaking of the models, says, 'We could not get along without them.'

To measure up stopes, transit stations are located in the stope, and sights to walls and breasts are taken. Assay values are recorded upon the outline of backs and breasts in the stope-books.

OLD DOMINION C. M. & S. Co.[1]

With this company, the party consists of transit man and one helper. The meridian is determined by sun observation, and

[1] Data furnished by N. H. Emmons, chief engineer.

carried underground by means of two piano wires in one shaft, held steady by 50-pound lead plumb-bobs, suspended in barrels of water. The top telescope is used for highly inclined shafts.

The stations are the ordinary spad in plug, or in cap where the drift is timbered. The stations are marked by brass tag nailed in plug or timber, and are numbered from 1 to 99 on the surface, and 100 to 199 on the first level, etc.

Angles are read from left to right and doubled for check. Notes are kept in printed loose-leaf note-books.

All measurements are read twice. Tapes, 100 and 150 feet long are used, but the 150-foot is preferred. Maps are made to the scale of 1 inch to 50 feet, upon paper about 2×6 feet, and each level is mapped upon a separate sheet. Platting is done by the latitude and departure method only. Blue-prints are taken every three months.

Stopes are measured up twice a month. Special stope-books of loose-leaf, cross-section paper, are used to sketch each floor of the square-set work.

No assay plans are kept. Direction and dip of bore-holes are determined by means of transit and clinometer.

Butte [1]

At the properties of the Anaconda Copper Mining Company and the Washoe Copper Company, the underground work is done by parties of two men each. The entire engineering corps consists of a chief engineer, five mining engineers, five assistants, and one draughtsman.

Instruments made by different standard makers are used. With some a top telescope is used; with others a side telescope, but the preferred auxiliary telescope is the interchangeable top and side.

The meridian used conforms with the courses of the side lines of the principal mining claims, and has been used for more than twenty years.

To carry the azimuth underground, two number 20 or 22 copper wires are used in one shaft, but after connections are made

[1] Practice described by Mr. August Christian, chief engineer of the Anaconda Copper Mining Company.

a check survey is made with one wire in each of two connected shafts.

The azimuth of the wires is taken off below, either by setting up in the plane of the two wires or by triangulation to them as is most convenient. Lead bobs, weighing 12 to 14 pounds, are used. These bobs are wing-shaped (Fig. 55) to prevent their turning in the bucket of water or oil in which the bobs are hung after all stretch has been taken from the wires.

The stations are brass screw-eyes (*f*, Fig. 46), set in timber or plugs. The screw-eye passes through a hole in stamped brass tag which serves to identify the station. Besides the screw-eye, two brass inch nails are also driven through holes in the tag to hold it securely. The system of numbering is: 'Consecutive numbers for all mines; no special care is taken to have consecutive numbers on any level; any number not previously used will be put up and recorded.'

The set-up is made only under the plumb-bob. A special illuminated plumb-bob target is used; Fig. 51A illustrates it. The bob is a heavy lead cube. The candle support rests upon the top of the lead, and a thin semi-cylinder of sheet copper protects the candle flame. The open side holds a sheet of mica, and just in front of the mica, and passing through the centre of gravity of the whole device, is the plumb-line.

Deflection angles are read.

Notes are kept by the loose-leaf system. The headings and form of notes are as follows:

TRAVERSE

Mine............................ Level............................

Rec. File No.................. Map No.............. Drift............................

Date	Station		Angle		Course			Distance	Eng.	Remarks
	From	To								

TRAVERSE EXTENSIONS

Mine.. Level..

Rec. File No......................... Map No................. Drift..

Date	Station		Course	Distance	Latitude		Departure		Station	Total Lat.	Total Dept.
	From	To			N.	S.	E.	W.			

LEVELS

Mine.. Level..

Rec. File No......................... Map No................. Location..

Date	B. S.	T. P.	F. S.	H. I.	Elevation	Remarks

Measurements are made on the horizontal wherever possible; elsewhere, slope distance and vertical angles are taken. For ordinary work, a 100-foot tape is used, but for shaft work a 250-foot tape.

Maps are of various sizes to suit the workings of the mines, but they are of uniform size for any particular mine. All maps of underground workings are to a scale of 40 feet to one inch. General or composite maps of the workings are made to a scale of 100 feet to 1 inch and 200 feet to 1 inch.

Surface maps showing buildings, railroads, contours, etc., are to a scale of 40 feet to 1 inch, also projections along the ledges showing ore extracted, are of the same scale. Surface maps showing groups of mining claims are made to a scale of 200 feet to 1 inch. A record and plat of the patent notes of each mining claim is kept in a claim-book.

Platting is done by means of coördinates. Surveys and maps are made of new workings each month. No blue-prints or photo-

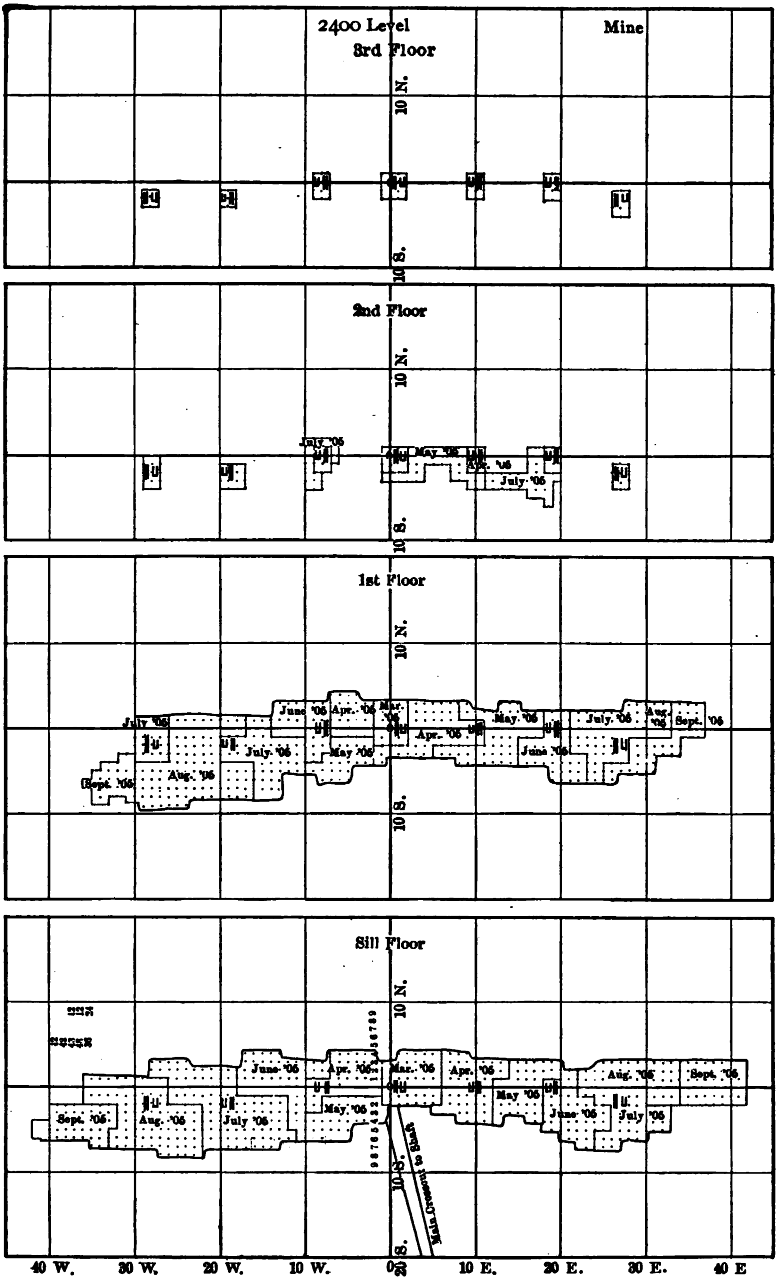
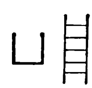


FIG. 78. — SHEETS FROM STOPE-BOOK.
(Colors and cross-section rulings not shown.)

graphs of maps are made. Mine models of wood, showing all workings have been made for court use only.

Transit-lines are run through levels and raises, only the stopes being measured and sketched in special stope-books. The mines are timbered with sets 5.83 feet square by 7.83 feet high, measured from centre to centre. These sets are framed in such a way that the upright posts of the first floor above the level rest upon the level posts; the posts of the second floor above the level rest upon the posts of the first floor, etc., until the next level is reached. These sets are numbered as shown on the four sketches (Figs. 78–81) which also show the system of keeping stope-books. Stopes are taken at the end of each month, and colored on stope-sheets, showing the progress of stoping for each month in a different color. The month and year is printed upon the space.

Cross-section paper is used for stope-books to avoid ruling them to scale. (Stopes are taken in about twenty mines.)

Each little square on the stope-sheets represents a set 5.83 feet square; floors are 7.83 feet high. The black dots represent posts in place. Near end of stopes where the ground taken out is not timbered, the engineer allows for ground stoped in his monthly report. The width of ore taken out each month is measured in each set in order to obtain correct quantities; sometimes two or three feet of ground is stoped outside of the regular square sets (see measurements recorded in sets 25 to 30 W., Fig. 78). The numbering of sets is always started where the main cross-cut from the shaft enters the ledge on each level. The signs  are used to locate ore chute and ladder or manway. In ledges where the stopes are not wide enough to admit timbering with square sets, the ground is cross-sectioned. Geological maps, which are tracings of the working maps, are kept up, showing the geology in different colors.

Diamond-drill holes are always laid out by the engineers to the true course and dip required, the engineer seeing that the drill is properly set. The foreman of the drill makes daily report of the progress of work.

Boston & Montana of Butte[1]

The Boston and Montana Consolidated Copper and Silver Mining Company of Butte, Montana, uses mountain transits made by different makers, and a transit with inclined standards for highly inclined work. The side telescope is also used for inclined work.

Two men compose the underground survey party. A backsight (Fig. 51B), consisting of a heavy metal base, which acts as a plumb-bob with a protected candle behind a sheet of tracing cloth, is used. This is carried forward from time to time by the assistant while the engineer is adjusting his transit. The foresight is a string suspended from the nail at the bottom of the station. This string has a small plumb-bob at the bottom and a movable tag to mark a point to which vertical angles are read.

By means of the backsight and foresight above given only one assistant is usually needed. In case of surveys through raises or shafts, two or more assistants are required.

Solar observations were taken years ago to determine the meridian, and have been checked several times since.

The usual method of carrying the meridian underground is by two wires in one shaft. Later on, when the workings from any particular shaft reach another shaft, the first survey is checked by suspending one wire in each shaft and then connecting the wires by two traverses, one on the surface or some level where the courses are known, and the other on the level where the courses are sought. These two traverses are adjusted to each other by calculation.

The shafts are usually three compartments, and the following sketch (Fig. 79) will show how the line is brought to the wires.

The wires are suspended at A and B in the two outside compartments, and from 10 to 12 feet apart. The transit is set at C, exactly in line with A and B. The angle is turned from A to E and the distance measured, while at some intervening point (D) a board is securely nailed to a post and a nail driven in the top on line C E. The surveyor then doubles his angle as a check. In order that the survey may be absolutely correct, the assistant now

[1] Data furnished by C. W. Goodale, manager, and Lee Hayes, chief engineer.

takes the transit, still standing at *C*, and reads the angles, measures the distance, and checks the point on line at *D*. The two surveys must agree, or the work must be done over. While the transit stands at *C*, a nail is driven on the inside of the shaft at the same elevation as the telescope; the distance is measured down from the known elevation of the station or tag at *E* to a horizontal line from the telescope. From the nail in the shaft, the elevations are carried down the shaft by tape measurement.

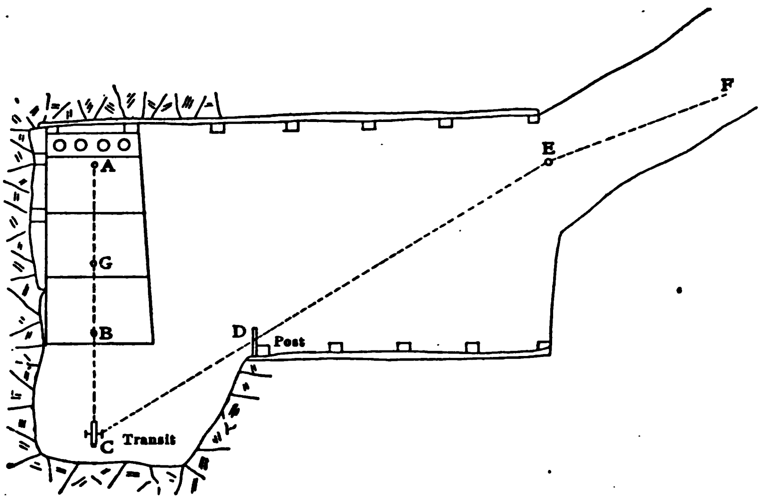


FIG. 79.—TAKING MERIDIAN FROM WIRES.

The transit is now moved to *E* and the angle between *C* and *F* is read, doubled, and checked by the assistant. The course *FE* is the known course, from which can now be calculated the course between the wires *A B*.

Meanwhile, on the level where the courses are sought, another surveyor and assistant are 'taking off' the line from the wires by exactly the same process as that described above. If only one surveyor and one assistant work, they can be lowered through the centre compartment. Two transits are, however, always used for this work. In case there is no space for the transit at *C*, the compartment *B* is planked over and the wire suspended at *G* while the transit is set at *B*. This gives a distance of about 7 feet between the wires. Two wires in one compartment have not given good results and that method is not used.

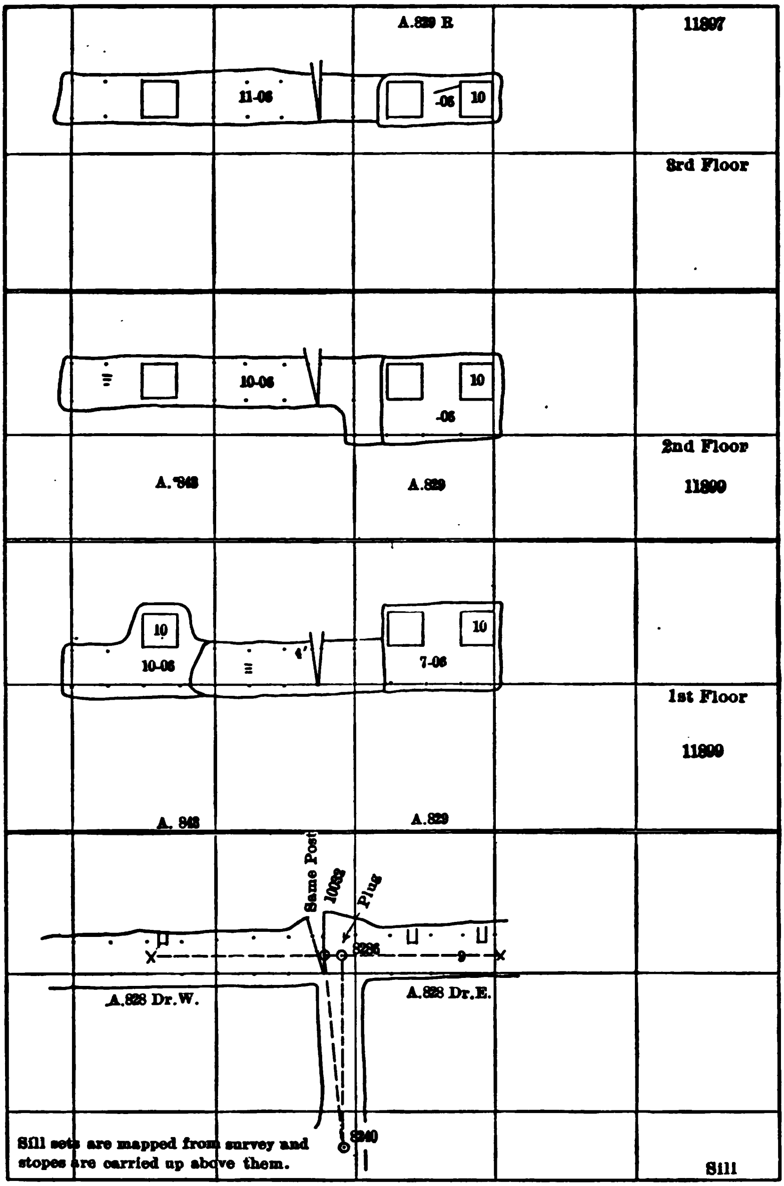


FIG. 80.—STOPE-BOOK SKETCHES FOR VEIN WITH ONE BEND.

Number 18 copper wire is used with 11- or 12-pound iron weights. These have been used through 1200 feet of depth.

The stations are marked by brass tags (1, Fig. 46) attached to the timber or plug. The stations are numbered consecutively from 1 to 99,999 or more. Several hundred tags are stamped at once, then one 100 is used in one mine, another 100 in the next, etc. No duplicates are used. The tags are used by number in order of survey, but with no reference to position in the mine. The transit is set up under the plumb-bob. Angles are read to the right, and doubled for check. Loose-leaf notes are used. Following is a sample on page 201.

The heading shows the place of work, names, the surveyor and assistant, followed by the date. '*C.* 10738' gives page where the calculations were made; '*L.* 5439' gives page where notes were copied in the ledger. In the ledger are found courses, coördinates and elevations, besides the written field notes.

The notes are in order from the beginning to the end of each book, so that dates and station numbers are in order. Each place in which a survey is made is indexed in the front of the book as well as in the ledgers.

Fig. 80 shows the stope-book sketches for the level and three floors above the level of a vein with one bend. The notes for the survey lines on the sill floor are as follows:

A 825 Dr. E. Line for Timbers. 8/9/06. Aber–Kane.

Transit	H. I.	Ang. R.	Courses Mag. and True	Vert. Ang. and Slope Dist.	H. P.	Station to Floor	Hor. Dist.	Description
8286 B. S. 8240	...	273° 24′	......	...	...	...	26.68	To nail centre last cap.
		186° 48′	S.32°58′E.	...	...	...	15.20	2.2 from N. post. } Round timbers.
							9.50	2.3 from N. post. }
A 828 Drift W. 11/14/06. Aber & Julian.								
10032 B. S. 8240	...	108° 11′	N. 42° W.	...	...	...	29.50	To 10032 E. side centre cap. To nail centre E. side cap.
		216° 22′	N.20°2′W.	...	...	...	...	Bend is at No. 10032.

15577 15577

C. 10738
L. 5439 A 304 D. E. BLAIR & FISHER. 1/4/07

Transit	H. I.	Ang. R.	Courses Mag. and True	Vert. Ang. and Slope Dist.	H. P.	o Sta. to Floor	o Hor. Dist.	DESCRIPTION
8712 B. S. S. 709	−2.16	186° 01′	S. 62° E.	....	+2.69	7.1	41.81	8754 W. side cap. 0.9 from N. post.
		19° 02′	S. 80° 0′ E.				36.2	To point 0.2 from S. post.
							17.6	To point 0.5 from S. post (sketch) below notes.

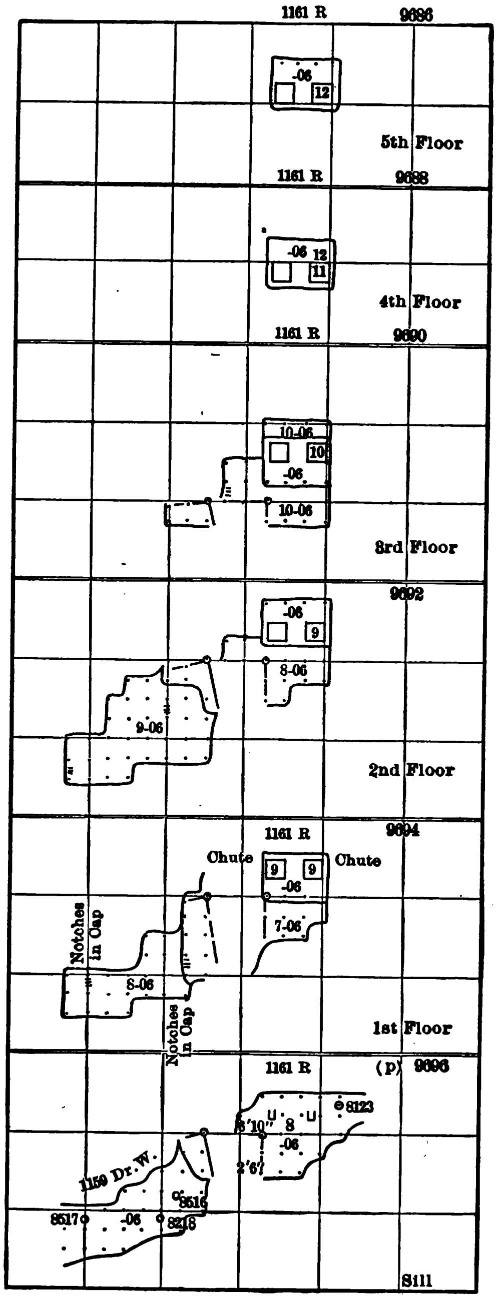


FIG. 81.—STOPE-BOOK SKETCHES OF VEIN WITH TWO BENDS.

Fig. 81 shows the field-book sketches of a vein and stope with two bends.

Fig. 82 shows the office maps as constructed from the above notes.

Field stope-books are on a scale of 20, 30, 40, and 50 feet to 1 inch. The 30 or 40 is found best for most veins. Inches are divided into 4, 6, 8, and 10 spaces, or 16, 36, 64, and 100 square inside the heavy lines.

Steel tapes of 25-, 100-, and 250-feet lengths are used for measurements. Maps are to the scale of 1 inch to 50 feet, drawn upon paper 18×46 inches. This size represents a double page in the large stope-books, in which all floors of all workings in the mines are mapped.

Angles are platted by coördinates. The extensions of workings are tinted by water color; a different color for each year.

United States Coal and Coke Co.[1]

In ordinary flat work, the party consists of three men, but on steep work, of five. The Y-level and 5½-inch engineers' transit are the instruments used.

The meridian is determined by observation on Polaris, and carried underground through drift by traverse.

The stations are spads (*n*, Fig. 46) driven into a coal or slate roof, or in a bored hole. Stations are marked on roof and on rib by white lead or spanish whiting. A transit-point is marked by a circle, a point on curve by a triangle and a bench-mark by a square.

The system of numbering is the same as that used in railroad lines, i.e., 48+00.6.

Set-up is made under the plumb-bob, and sight is made on plumb-bob string backed by a piece of white paper with lamp behind it. The method of continuous azimuth is used.

[1] Survey methods furnished by Mr. Howard N. Eavenson, chief engineer.

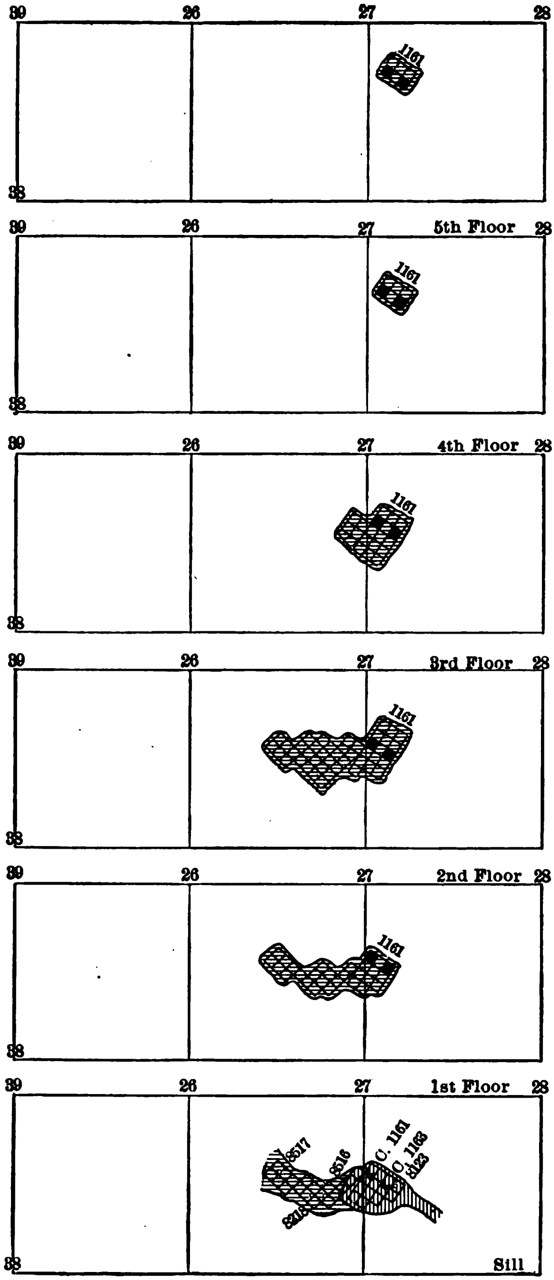


FIG. 82.—OFFICE MAP COMPILED FROM STOPE-BOOK SKETCHES.

The company issues a letter and specimen page (Fig. 83) of field-notes to its surveyors. This is given in full as follows:

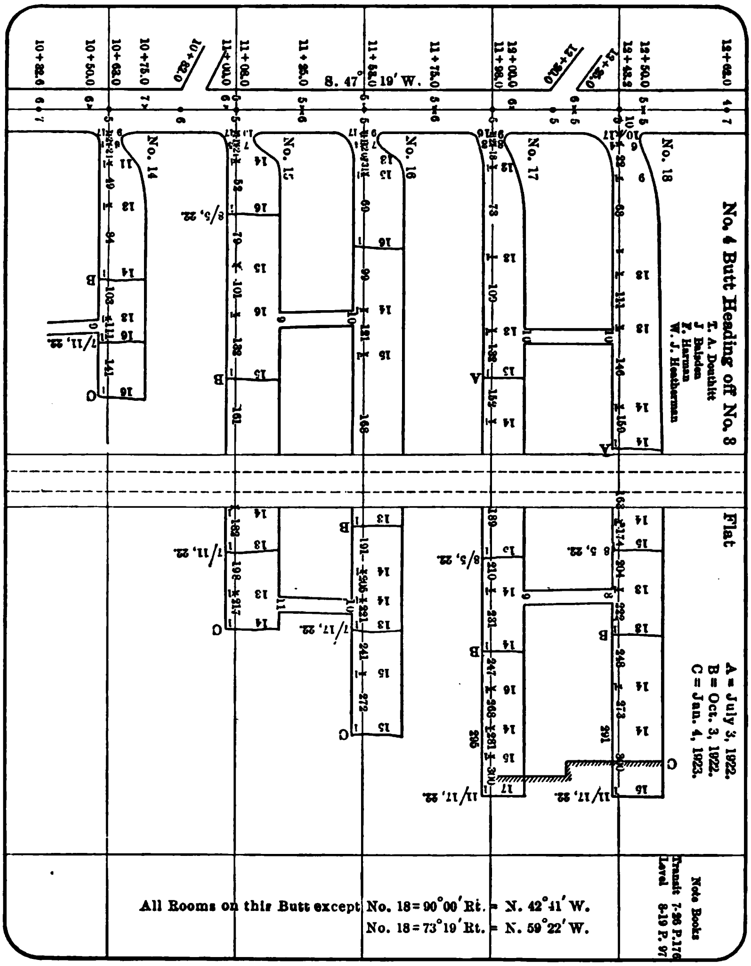


FIG. 83.—SPECIMEN PAGE OF FIELD-NOTES.

'UNITED STATES COAL AND COKE COMPANY METHOD OF RECORDING MINE SURVEY NOTES

'CARY, W. VA., August 19, 1903.

'In room notes, draw a line across each room for face at date of each survey, as at *A*, *B*, etc., and record survey letter for each

room, as at *A*. The date of survey, with survey letter after it, must be written at top of page (as *A*, July 5, 1922). Consecutive letters, *A*, *B*, *C*, etc., are to be used for consecutive quarterly surveys, beginning in each mine when first rooms are turned. For intermediate surveys, use dates, and no letters. Note all distances as being total from transit-point in heading. Enough measurements must be taken to show clearly the shape of the excavation; they must be taken to side of heading at mouth of rooms, to end of necks of rooms, to first point where rooms reach full width, to near side of all cut-throughs, to faces of rooms at date of survey, and in general, to all points where directions of sides of rooms change. Allow sufficient space to show rooms and pillars clearly, so that figures, dates, etc., are not obscured.

'In making draw-back line, use a broken line and widely spaced hatching; thus: and mark distance drawn back from the centre of heading on room pillar (see sketch). Use some date (or letter) for recording date of draw-back line as for the full regular surveys, as at *C*.

'In heading notes, draw a line for face of heading, and mark date clearly at this line. Measure and record distances right and left to the sides of headings and rooms at points not greater than 25 feet apart, and less where decided changes of width take place.

'These same notations, including lines for face, at date of survey, marked across headings and rooms must be used on all mine maps. The letters are to be at faces of rooms and are to correspond with date of last survey as marked on map, and placed after this date; thus: (date of last survey January 4, 1923, *A*). Dates instead of letters are to be used for faces of headings.

'All rooms are to be turned by angles from transit-line in headings, to be recorded in notes (see Fig. 100).

'Records are to be made of both transit and room notes.

'CHIEF ENGINEER.'

[1]Tapes of 100 and 300 feet in length are used. Maps are made to the scale of 1 inch to 100 feet, upon paper 58 inches wide and as long as may be necessary. The main lines are platted by co-ordinates and extensions by steel protractors reading to minutes. Blue-prints are taken quarterly.

Figs. 84 and 85, show maps of workings and workings projected in advance. All headings, rooms, etc., are driven on line sights.

[1] Methods used in Rocky Mountain collieries. *M. & M.*, Sept. 1909.

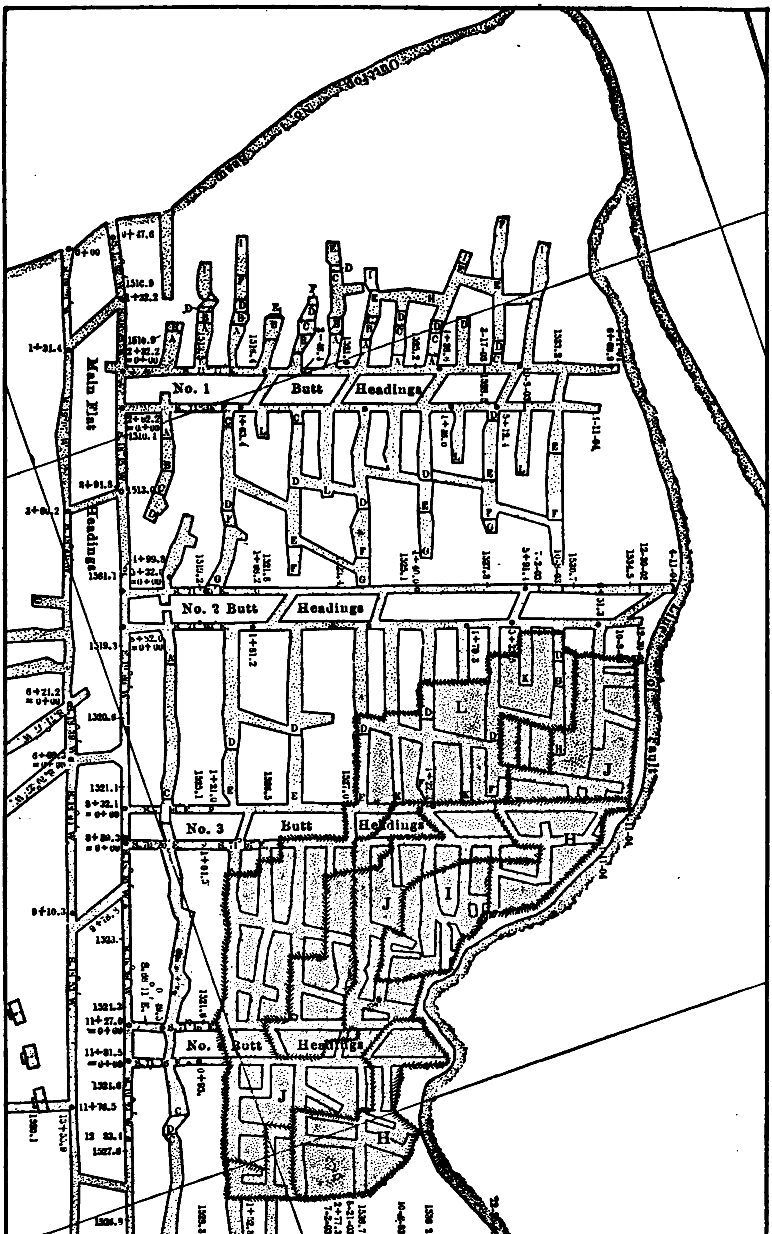


FIG. 84. — MAP OF WORKINGS OF COAL MINE.

Homestake

At the Homestake Mining Company's property, Lead, South Dakota, the underground party consists of the transit man and two helpers. The meridian is determined by Polaris or by direct sun observations. The side telescope is used, but for vertical sighting on short base it is not relied upon. The regulation plumb-line methods for carrying azimuth underground are employed. Number 20 or 22 copper or brass wire is used. The azimuth is taken off underground by setting the transit up in the plane of the two wires and then lining in the plumb-line notches in spads. To hold the plumb wires steady, fifteen- or twenty-pound cast-iron weights are immersed in cans of water, usually five-gallon oil cans. Stations are plug and triangular-notched spads, and are not marked, the notes and sketch being sufficient to identify them. The underground stations are not numbered, but surface stations each carry a number.

The set-up is generally made over a point (nail) carried to the floor. Where necessary, the instrument is set up under a plumb-bob. In low openings, the instrument is sometimes used without tripod.

Deflection angles are read and checked, and courses afterward referred to azimuth.

Notes are kept on $4\frac{1}{2}\times 6$ inch cards ruled 8 to an inch in light blue. Upon these, a sketch of the work done is made and the deflected angle and length of course written upon the sketch.

Side notes are taken by radiating side-shots to points around irregular openings. Levels are carried through the principal headers and to shaft-stations and bench-marks made.

Measurements are made with 100- or 400-foot steel tapes. Maps are to the scale of 50 or 100 feet to 1 inch and upon paper 60×100 inches in size. The principal courses are platted by latitude and departure, but unimportant side-shots by protractor. Extensions of the survey are shown upon the map by dotting new outlines and erasing the old lines of stope margin. Blue-prints of special sections are taken as required.

Stopes are surveyed by counting square sets from some reference point. Regular cross-section paper, as near the scale of working map as can be procured, is used to sketch the sets and outline of each floor of the stope.

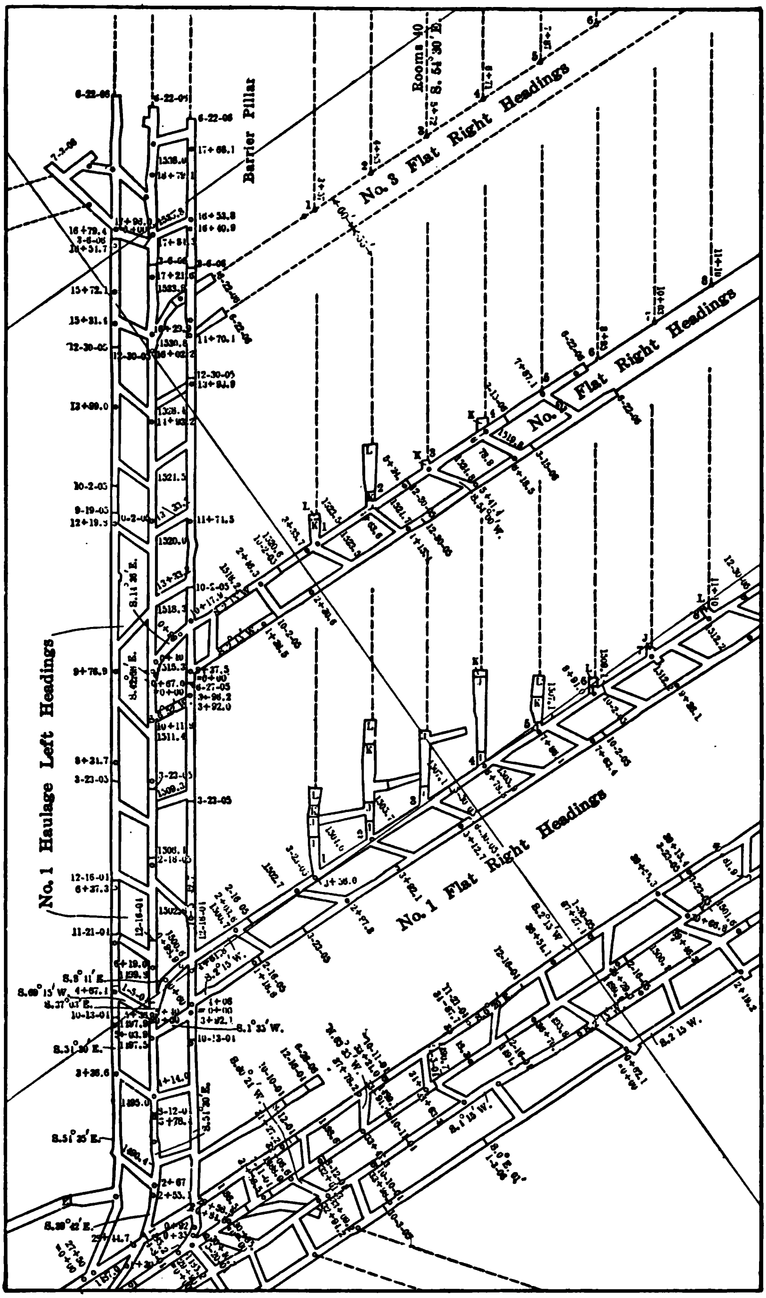


FIG. 85.—MAP OF WORKINGS AND PROPOSED EXTENSIONS.

No record of samples or assays is made on a map. This record is kept by the 'Sampler' in his record-book by name of stope or drift.

The inclination of the drill-rods in bore-holes is taken and azimuth of bore found by plumbing points to the floor. The rods are measured for depth.

A Quick Vertical Shaft Survey[1]

'This article deals with the method I have used for fifteen years in making quick and accurate surveys of various vertical shafts in Amador and other counties along the Mother Lode of California.

'The essential features of the method are the use of heavy plummet lines and "bobs" hanging free while being set, but securely fastened while observations are being taken. I can best illustrate the operation of this method by citing an actual case, that of my survey of the Oneida vertical shaft in six hours on July 6, 1902. This main working shaft of the mine was sunk 1000 feet east of the outcrop and intersected the vein, which dips to the east, 1900 feet, below the surface. The vein was then being worked through six levels at 1200, 1500, 1700, 1800, 1900, and 2000 feet, vertically below the collar of the shaft.

'The adverse conditions under which this survey was made were: A very wet shaft, through which water literally poured in torrents; a shaft distorted and narrowed by swelling ground at the 1800-foot level, and a shaft with an excessive number of working levels into each of which the survey had to be tied from one hanging of the plumb-bobs and as quickly as was consistent with good work, so as to interfere as little as possible with the regular operation of the mine and the use of the shaft.

'To overcome these adverse conditions, two large-sized (number 12 gauge) soft-drawn iron wires were suspended in the centre compartment of the shaft, with a 125-pound plumb-bob attached to each, less than one foot below the 2000-foot level, the wires sliding from the surface with the bobs attached, through notches in plank. At the 2000-foot station, opposite each wire, a template, made from a piece of candle-box, was so placed and fastened with a wire nail at one end that the free end could be swung or moved to or from the wire in a horizontal direction practically in line with

[1] Written by W. E. Downs, for the *Mining and Scientific Press*, August 25, 1906.

both wires. By the interposition of a small piece of wood laid loosely upon each template, with its end projecting over, and in contact with, the advancing side of the oscillating wire, the latter was brought to rest after the retardation of a very few oscillations. The position of rest was then carefully marked on the template. As the oscillations diminished, the template was brought closer to the wire until finally, when the latter was at rest, the template was brought in contact with it and nailed in place. The wire was then fastened to the template from underneath, in the position of permanent rest.

'Seven settings with a transit were made, one at each station and one at the collar of the shaft, all in the same vertical plane. In each instance the instrument was set, by the "cut and try" method, as near the nearest wire as the minimum focal distance (about six feet) of the telescope would permit, with a lighted candle in range beyond the farther wire. When in this position, the telescope may be focused on either wire and accurately adjusted to the exact plane of both; this was done in each instance. The slightest sidewise tremor of either wire, which neither lasted long nor caused serious delay, was readily detected. From each setting wire nails were accurately centred on line and driven into solidly placed track ties, plugs, timbers, or planks, and steel-tape measurements to the nearest hundredth of a foot made to locate them with reference to the wires — all in the same vertical plane. Subsequently, from these nails, courses were extended by deflection throughout each level and to the previously established surface boundaries and all necessary measurements made, whereby the position of each point, or instrument-station, in the whole system was determined with reference to every other point. From these data the entire system was accurately mapped and the field-notes tabulated for future reference, so that the survey could be extended and mapped as development work progressed.

'In this survey the horizontal distances between plummet-wire centres were respectively: 2.43 feet at the collar, 2.44 feet at the 1200-foot level, and 2.45 feet at the 2000-foot level. The divergence of these wires downward is due to but one cause, which is purely gravitational. The mass of rock that would have to be in place between the wires to have them hang parallel, or, more theoretically to converge toward the centre of the earth, was absent, and of course the wires came to rest, diverging slightly downward.

Drafts and falling water in the shaft do not have any effect upon the sum total of this divergence, although they do create tremors and also operate to check the same.

'In contrast with the hard-drawn piano-wire method of hanging bobs of necessarily light weight in molasses or some other viscous liquid, this method has no equal; it is quick and reliable, it has proved so to my entire satisfaction in numerous instances where I have made surveys for underground connections.

'A plummet line of large-sized soft-drawn wire has two decided advantages over one of small-sized hard-drawn wire; they are as follows:

'First. In the process of hanging wire, all kinks and internal strains are absolutely removed by stretching, leaving the wire perfectly straight, a condition impossible with hard-drawn wire wherein kinks and strains are left, subjecting the wire to local wobbles nearly as great as the diameter of the wire itself.

'Second. As external disturbances, due to drafts and falling water, are of a magnitude proportionate to the exposed surface of the wire, and as the strength of a wire is proportional to the square of its circumference and therefore to the square of its exposed surface, it is plain, although a hard-drawn wire is stronger per unit of cross-sectional area than a soft-drawn wire, that if the difference in size is great enough, a large soft-drawn wire is better adapted to withstand said disturbances than a small hard-drawn wire. The so-called advantage of being able to bisect a small-sized wire with the vertical cross-hair of the instrument better than a large-sized wire is in practice a myth, particularly when contrasted with our first advantage.

'The bobs must be symmetrically made, preferably of solid shafting accurately turned in a lathe and centred with an eye at one end to receive the plummet wire. This wire must be a continuation, when suspended, of the axis of the bob, so that there will be no local wobbles in the wire when the bob revolves, which it will do to a small extent.'

A Method for the Survey of a Wet Mine-Shaft[1]

'Some time ago the writer, while engaged in the survey of some old mine workings, had occasion to devise a method for the carry-

[1] By Mark Ehle, Jr., in *The Aurum*, March, 1906.

ing of a line between two adjacent levels via a short length of inclined shaft, the same representing such features as to render ordinary methods of procedure inapplicable. Reference to the accompanying figure will make clear the conditions.

'The incline in question was the only available opening connecting the levels, and therefore had to be utilized. It had a length of some eighty feet, between levels, and dipped at an angle of about seventy-five degrees for the upper sixty feet, changing to a somewhat flatter angle throughout the remaining distance. It comprised one ladder and two hoisting compartments. The ladderway, while available for travel between levels, offered by its arrangement, serious, if not insurmountable, obstructions to the work at hand. The adjacent hoisting compartment was half full of rock, having been used as an ore bin. The outer hoisting compartment, though open, presented its difficulties in the form of descending water, which, falling in large quantities from the hanging side, dropped to the other, and in rebounding, filled the lower portion of the compartment with a heavy shower of descending drops.

'The traverse having progressed to the station *P* (Fig. 86) in the upper level, a set-up was made under this station, and by means of an auxiliary top telescope, a sight on the point *B* was defined by a pin-thrust through a plumb-line suspended from station *H*; the pin being rendered visible by a background of illuminated oiled paper, stretched over one end of a tin can, a candle flame within, thus being protected from the falling water. In order to prevent vibration of the line, due to the heavy drops of water striking it, some strips of old tin roofing were placed as a protection throughout the greater portion of its length.

'A satisfactory sight on *B* having been obtained, the necessary measurements of azimuth, slope distance, vertical angle, *HI*, etc., were taken. Going below, a set-up was now made under station *H*, the transit being protected from the falling water by an improvised tin roof. Through an opening in this roof a backsight on the plumb-line suspended from station *P* was attempted, but failed utterly, as any opening in the roof, large enough to permit of discovering the plumb-line, admitted such quantities of water, in the form of spray, that not only the objective was blurred, but the cross-hairs were endangered by water entering the tube of the instrument. To add to the difficulty, the din of the falling water

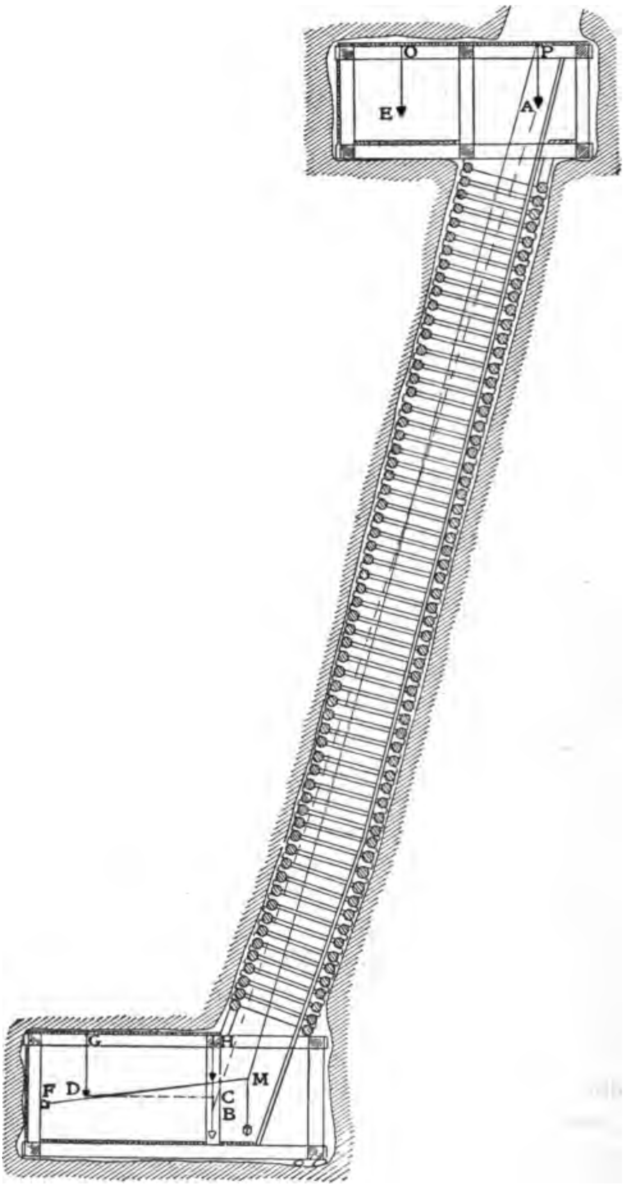


FIG. 86.—INCLINED SHAFT SURVEY BY BENT LINE.

vetoed all attempts at vocal communication up or down the shaft; but by rappings on the old air pipe, which extended up the ladder-way, a crude system of signals was arranged and used.

'Having failed to obtain a backsight by this method, the following was devised and successfully used: A strong, water-proof fishing line was suspended from station *P* in such a manner that it would in any event define a plane with the plumb-line suspended from the same station. This silken cord was then passed down the incline and carried out into the lower level, being temporarily fastened to the old air-pipe running along the opposite side of the drift. A twelve-pound plumb-bob having been suspended from the cord at the point *M*, the lengths of cord on either side of *M* were kept taut, and in any position, the lines of these two lengths defined a plane containing the point *P* above. This plane was then shifted by moving the lower point of attachment of the cord along the pipe to a point *F* which brought the lower length of cord exactly under the plumb-line suspended from *H*.

'Another small bob was now hung from a point *G* in the lower drift. The point of this bob was centred over the small cord stretched below, which was then removed to one side.

'The setting of the plumb-line at *G* in the manner described, insured of its being in the same vertical plane of the plumb-lines from *H* and *P*, and at once rendered a set-up under *H* unnecessary; for, having the azimuth of the course *A B*, the azimuth of such a course as *C D* becomes identical with it, and a set-up under station *D* gives all other information regarding the relative positions of stations *H* and *G*.

'By the use of so heavy a bob at *M*, all vibration of the small cord was absorbed, and no difficulty from this source was experienced.'

A Mining Survey [1]

'A high degree of accuracy is often required in mine-surveying, in order that expensive mining work may not be misdirected. The making of underground connections by drifts or shafts located as the result of surveys presents a crucial test of correctness not usually involved in any other class of surveying. In view of these

[1] Reprint of article by J. F. Wilkinson, *Trans. A. I. M. E.* (Canadian Meeting, August, 1900).

considerations, the present notes and description of a survey made in June, 1890, for the San Francisco shaft of the New Almaden quicksilver mines, may be of interest to members of the Institute who are surveyors.

'The purpose of this survey was to locate on the surface a vertical 2-compartment shaft (3.5×7 feet), to connect with another vertical shaft, of practically the same size, which had been sunk a number of years before from an adit-level about 240 feet vertically below the surface, to a deeper, so-called 600-foot level. It will be seen, of course, that the most important matter was to secure an exact coincidence in vertical line, so that the resulting continuous vertical shaft from the surface should have no offset or irregularity at the point of junction between its two parts. The levels were of less importance; but, as the hoisting-works were to be placed in position and the new shaft permanently timbered from the start, its correct alignment was an essential requirement. The important features of the work, therefore, were the methods used in determining with certainty: (1) That the shaft was located in the right place in a general way; (2) that the ordinary inaccuracies of linear and angular measurements were so reduced as to insure correctness of location within certain defined and allowable limits.

'*Instruments.* — The instruments used were: a Buff and Berger transit-theodolite, with a 6-inch horizontal plate, reading to 10 seconds; a Heller and Brightly Y-level; a Chesterman steel tape, graduated in tenths and hundredths of a foot; and New York leveling-rods, graduated to thousandths of a foot.

'The leveling-rods and tape were compared with a standard of measurement, and the correction for each was ascertained. In the case of the tape, the conditions for the standard were, that the pull should be 16 pounds; that the tape should lie horizontally on the ground; and that the temperature should be 70° Fahr. (this being the average temperature in the adit underground). Three corrections were thus actually necessary for each tape-measurement, viz.: to reduce to the standard; to correct for the catenary curve; and to correct for difference in temperature.

'While the graduations on the tape were made to hundredths, yet, in careful measurements, it was possible to estimate thousandths of a foot, thus making these readings correspond in minuteness with those obtainable on the leveling-rods.

'Of course, to do this underground, it was necessary to use very fine fish-cord for plumb-lines; and, on the surface, measurements were made between small headless wire nails in stakes previously aligned by means of the transit. Here the hypotenuse was thus obtained, while the vertical component was obtained by leveling; and from these the horizontal component was calculated in the usual manner. Underground measurements were made on a practically horizontal plane, by means of marks on plumb-lines previously aligned by the transit, and leveled.

'To correct for the catenary curve, the weight of the tape per foot was ascertained, and the correction was calculated by the usual formula. For a tape weighing 0.00725 pound per foot, with a pull of 16 pounds (exerted in all measurements by means of spring-balances), the correction to be applied in 100 feet is 0.00855 foot, and in 50 feet only 0.00107 foot.

'For temperature, the correction in 100 feet for a difference of 1° Fahr. is 0.00069 foot. Most of the measurements in the adit were made at a temperature not varying appreciably from the assumed standard. On the surface, however, the temperature in some instances varied from the standard as much as 20° Fahr.

'In making the angular measurements, the greatest care was taken; and, by the most approved methods — repeating angles, reversing the telescope, reading both from right to left and from left to right, etc. — all possible instrumental errors, unavoidable errors of adjustment, and personal errors of observation, were eliminated. All angles were read at least twice; and in some cases as many as four readings of ten repetitions each were taken. The number of times each angle was read, and the number of repetitions in each case, are shown in column 4 of Table I. By the means thus employed, the angular measurements were made certainly correct within one second.

'*Preliminary Survey.* — In the preliminary survey, the mean of two sets of tape-measurements was taken. For the surface line, besides the tape-measurements, two sets of levels were also run. As to the surface line (Monument M. to Monument S. F.), it may be observed that neither monument was visible from the other; so that, in order to define the line, several settings of the transit at intermediate points were necessary. The different measurements reduced, the calculations made, and the results obtained in this—the first complete—survey, are shown in Table I; and, for their

TABLE I.—PRELIMINARY LOCATION (AVERAGE OF TWO SURVEYS)

Station	Mean Deflection	Calculated Bearing	Angular Measurements (Number)		Horizontal Distances, Corrected for Temperature and Catenary and Reduced to Standard			N.	S.	E.	W.	Coördinates		Station
			Of Obs.	Of Rept.	Obs. 1	Obs. 2	Mean					+N.	+W.	
Mon. M. to Mon. S. F.		S. 86° 58′ 56″ W.	...	...						...		000.000	000.000	Mon. M.
Mon. M. to 1	45° 5′ 34″ I Rt.	N. 47° 55′ 30″ W.	4	10	403.080	403.080	403.080	270.105		...	299.193	270.105	299.193	1
1 to 2	74° 5′ 6″ Lt.	S. 57° 59′ 24″ W.	4	5	587.207	587.209	587.208		311.260	...	497.926	−41.155	797.119	2
2 to 3	32° 23′ 43″ Lt.	S. 25° 35′ 41″ W.	4	6	67.000	66.999	67.000		60.425	...	28.944	−101.580	826.063	3
3 to 4	54° 43′ 47″ Rt.	S. 80° 19′ 28″ W.	4	6	44.803	44.804	44.803		7.530	...	44.166	−109.110	870.229	4
4 to 5	39° 51′ 57″ Rt.	N. 59° 48′ 35″ W.	4	6	41.075	41.075	41.075	20.656		...	35.504	−88.454	905.733	5
5 to Cor. A	31° 10′ 10″ Rt.	N. 28° 38′ 25″ W.	2	3	19.573	19.573	19.573	17.178		...	9.382	−71.276	915.115	Cor. A. Corners of shaft on adit-level.
5 to Cor. B	Do.	Do.	2	3	27.238	27.242	27.240	23.907		...	13.056	−64.547	918.789	Cor. B.
5 to Cor. C	39° 43′ 40″ Rt.	N. 20° 04′ 55″ W.	1	2			21.477	20.171		...	7.374	−68.283	913.107	Cor. C.
5 to Cor. D	24° 2′ 40″ Rt.	N. 35° 45′ 55″ W.	1	2			25.773	20.913		...	15.063	−67.541	920.796	Cor. D.
Mon. M. to Mon. S. F.		S. 86° 58′ 56″ W.	...	...	896.801[1]	896.792[1]	896.796		47.213	...	895.553	−47.213	895.553	Mon. S. F.
Mon. S. F. to Cor. A.	47° 52′ 22″ Lt.	S. 39° 6′ 34″ W.	1	...			31.011		24.063	...	19.562	−71.276	915.115	Cor. A. Points given for location of shaft on surface.
Mon. S. F. to Cor. B.	33° 42′ 18″ Lt.	S. 53° 16′ 38″ W.	1	...			28.989		17.334	...	23.236	−64.547	918.789	Cor. B.
Mon. S. F. to Cor. C.	47° 11′ 02″ Lt.	S. 39° 47′ 54″ W.	1	...			27.424		21.070	...	17.554	−68.283	913.107	Cor. C.
Mon. S. F. to Cor. D.	35° 49′ 36″ Lt.	S. 51° 9′ 20″ W.	1	...			32.410		20.328	...	25.243	−67.541	920.796	Cor. D.
Test of Connection														
4 to 5														
5 to Wire Cor. C_1	39° 35′ 25″ Rt.	N. 20° 13′ 10″ W.	1	2			21.507	20.182		...	7.433	−68.272	913.166	Wire Cor. C_1 On adit-level. A wire freely suspended approximately at corner C.
Mon. M. to Mon. S. F.			...	...										Do. On surface.
Mon. S. F. to Wire Cor. C_1	47° 5′ 43″ Lt.	S. 39° 53′ 13″ W.	1	2			27.454		21.066	...	17.606	−68.279	913.159	
								Difference				0.007	+0.007	

[1] In determining these distances two sets of levels were run.

better elucidation, a horizontal plan (Fig. 87) and a vertical section (Fig. 88) of the tunnel and shaft are also appended.

'The shaft was located by this survey, the notes having been carefully calculated and checked, use being made of Bruhn's tables of logarithms, also of the natural functions from tables by

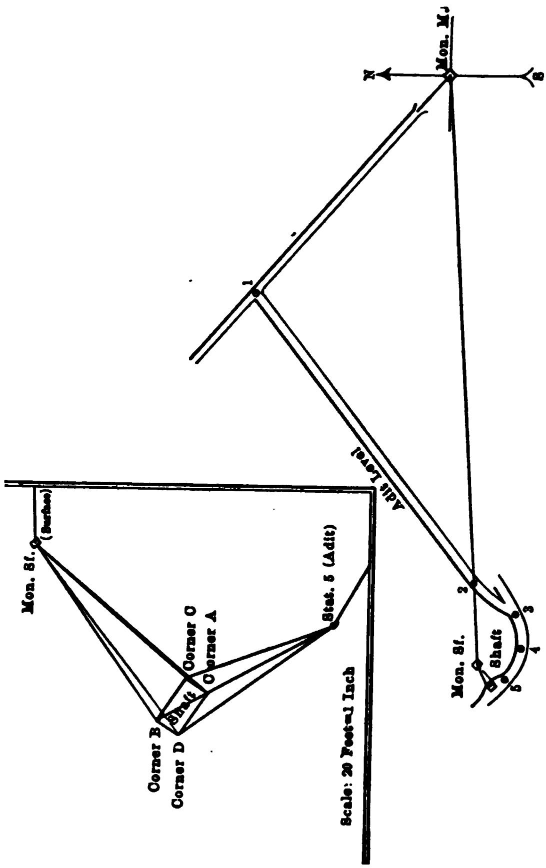


FIG. 87. — HORIZONTAL PLAN OF SHAFTS AND ADIT.
Scale: 200 Feet = 1 Inch.

a different author, thus eliminating any possible error due to misprints or other causes.

'*Check-Survey.* — As a further precaution, to satisfy the first condition imposed, and guard against the overlooking of any glaring error in the work, a second complete survey was made,

a week or more after the first. This, while made as a separate independent survey, also served to eliminate any errors of the first survey which might have been due to faulty setting up of the transit, inaccurate centering over the stations, or sighting at the wrong station. The angles being taken differently (all being interior angles, from which the deflection angle was obtained by subtracting from 180°), any such error would have become apparent. In determining the surface line only one set of levels was run; but an entirely different set of intermediate stakes was used, thus eliminating the possibility of *repeating* an error in this part of the work.

'In making the calculations, besides those shown in Table I., the additional precaution was taken, in the check-survey, of assuming one course as a meridian line (Monument M. — Monument S. F.) and coördinating the different stations with reference to Monument M. by courses thus obtained.

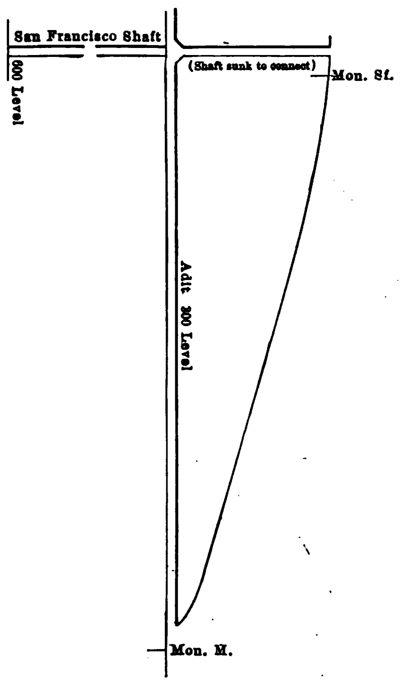


FIG. 88. — VERTICAL SECTION OF SHAFTS AND ADIT.

Scale: 200 Feet = 1 Inch.

'Table II. shows the results of the check-survey.

'All results, however, indicated a certainty that the shaft was correctly located for all practical requirements, and to the strong probability that the corners of the shaft, as located on the surface, did not differ in coincidence from the corresponding corners on the adit-shaft by more than ¾ of an inch.

'When the connection was made, no horizontal displacement in vertical alignment was detectable; but, to test the accuracy of the survey more closely, a fine steel wire, to which was attached an 18-pound plumb-bob, was suspended from the collar of the shaft to the adit below. A point was selected at approximately the

TABLE II.—CHECK-SURVEY

Station	Mean Deflection (All Angles Being 180° Minus Intermediate Angles)	Calculated Bearing	Angular Measurements (Number)		Horizontal Distances, Corrected for Temperature and Catenary and Reduced to Standard			N.	S.	E.	W.	Coördinates		Station
			Of Obs.	Of Rept.	Obs. 1	Obs. 2	Mean					+N.	+W.	
Mon. M. to Mon. S. F.	......	S. 86° 58′ 57″ W.	...	...	......	......	......	......	......	......	......	000.000	000.000	Mon. M.
Mon. M. to 1	45° 5′ 33″ + 1Rt.	N. 47° 55′ 30″ W.	4	10	403.074	403.078	403.076	270.102	......	......	299.190	270.102	299.190	1
1 to 2	74° 5′ 05″ Lt.	S. 57° 59′ 25″ W.	2	10	587.205	587.207	587.206	......	311.256	......	497.926	−41.154	797.116	2
2 to 3	32° 23′ 45″ Lt.	S. 25° 35′ 40″ W.	2	6	......	......	67.000	......	60.426	......	28.944	−101.580	826.060	3
3 to 4	54° 44′ 31″ Rt.	S. 80° 20′ 11″ W.	2	6	......	......	44.808	......	7.522	......	44.172	−109.102	870.232	4
4 to 5	39° 50′ 18″ Rt.	N. 59° 49′ 31″ W.	2	6	......	......	41.070	20.643	......	......	35.505	−88.459	905.737	5
5 to Cor. b.	31° 10′ 47″ Rt.	N. 28° 38′ 44″ W.	2	3	......	......	27.246	23.911	......	......	13.061	−64.548	918.798	Cor. b.
Mon. M. to Mon. S. F.	......	S. 86° 58′ 57″ W.	...	...	......	......	896.756	......	47.206	......	895.513	−47.206	895.513	Mon. S. F.
Mon. S. F. to Cor. b.	33° 39′ 37″ Lt.	S. 53° 19′ 20″ W.	1	...	......	......	29.033	......	17.342	......	23.285	−64.548	918.798	Cor. b.

Test of Connection

4 to 5	......	N. 59° 49′ 31″ W.												
5 to Wire Cor. C_1	39° 35′ 25″ Rt.	N. 20° 14′ 06″ W.	1	2	......	......	21.507	20.180	......	......	7.439	−68.279	913.176	Cor. C_1 Wire. { Adit-level.
Mon. M. to Mon. S. F.	......	S. 86° 58′ 57″ W.												
Mon. M. to Wire Cor. C_1	47° 5′ 43″ Lt.	S. 39° 53′ 14″ W.	1	2	......	......	27.454	......	21.066	......	17.606	−68.272	913.119	Cor. C_1 Wire. { On surface.
								Difference				+0.007	+0.057	

position of the originally located corner, C (called Wire Cor. C_1 in the notes). This was possible without fear of the wire touching the sides of the shaft, for the reason that the shaft had been made several inches wider and longer than the collar-set of the adit-shaft. To prevent oscillation, the plumb-bob was immersed in a mixture of molasses and water. Then, having ascertained that the wire hung freely without touching the sides of the shaft, or any other object, at any point, its position was instrumentally observed at both the surface and the adit-level. The co-ordinates thus obtained are shown in the tabulated notes. The difference between the two sets of coördinations is the error of the survey, and is shown in both the preliminary and the check-survey.

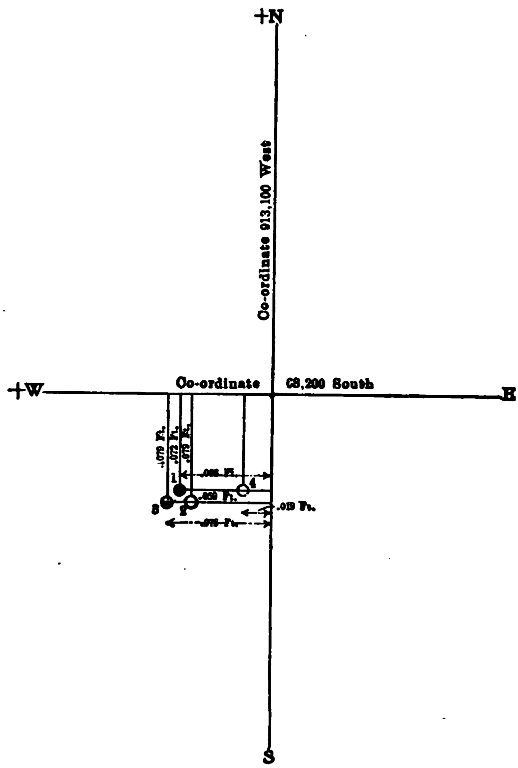


FIG. 89. — POSITIONS OF $\left\{ \begin{array}{l} \text{WIRE} \\ \text{CORNER } C_1. \end{array} \right.$

Natural Scale: 1 Foot = 1 Foot.

'It must be said that the conditions under which the survey was made were most favorable for the surveyor. The two assistants employed were reliable and experienced in that class of work; and, as no mining was being done in that part of the mine at that time, there was neither tramming, blasting, powder-smoke, nor changeable draughts to interfere with observations or distract attention. On the surface, the atmosphere was clear and the air steady; and, during the first part of the survey, there was very

little wind. A sufficient length of time was allowed, so that nothing was slighted or overlooked on account of undue haste.

'In summary review, the special features to be noted are: (1) The means taken to insure the location of the shaft in the right place (two independent surveys and check-calculations); (2) the methods used to reduce the ordinary inaccuracies of survey within allowable limits; and also the practical demonstration, here given, of the accurate results attainable by the use of the usual surveying instruments and measuring apparatus, as described, when the most approved methods of observation are carried to the extreme, and neither time nor care is spared to make the results as nearly perfect as possible.

'Fig. 89, drawn to natural scale, illustrates the final result of the surveys.

'In this figure, the circle numbered **1**, and completely filled with black, shows the position of Corner C_1 Wire, as coördinated from the adit-level by first survey; the open circle, numbered **2**, that of Corner C_1 Wire, as coördinated from the surface by first survey; the half-black circle, numbered **3**, that of Corner C_1 Wire, as coördinated from the adit-level by second survey; and circle numbered **4** (open, with a heavy horizontal diameter), that of Corner C_1 Wire, as coördinated from the surface by second survey.

'By the location-survey the shaft was 0.007 foot too far south; and 0.007 foot too far east; by the check-survey, it was absolutely correct north and south, and 0.047 foot too far east.

'By averaging the two surveys, giving to the location-survey twice the importance or "weight" of the check-survey (because all of its measurements were made twice, while in the check-survey some were made only once), we have the average error of the survey; the shaft thus being 0.0047 − feet too far south, and 0.0203 + feet too far east.

'This applies to the other three corners, as well as to Corner C.'

XII

EXAMINATION FOR COMMISSION AS U. S. DEPUTY MINERAL SURVEYOR

THIS examination in Colorado consists of problems in calculation of closing line in a twelve- or thirteen-sided placer, together with calculation of area by Double Meridian Distance Method, calculation of lode line to fit an irregular claim, calculation of ties, intersections and areas in an actual approved survey together with writing up a complete set of field-notes. A problem on the subdivision of a section of the public survey is usually added. The applicant is also required to determine a correct meridian from solar observation, and must do this with his own transit. There are, of course, other problems but they in no way differ from those numerous examples that have been given and explained in the course of this work. A few examples will, however, be given in detail to illustrate special cases. One favorite problem which is of considerable importance is the one first mentioned above and is as follows:

Placer Calculations. — Given: The courses and lengths of lines 1 to 13 of a certain placer (Fig. 90). It is desired to amend the survey making Cors. Nos. 2 and 12 identical with the corners of the original survey, the courses of lines 1–2 and 12–13 to remain the same, and the course of line 13–1 to be S. 33° 34′ E., the new placer to contain an area of 35 acres. Required, the lengths of lines 12–13 and 1–2.

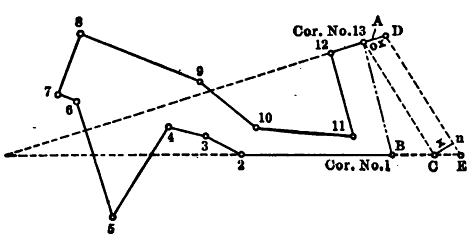


FIG. 90. — MAP OF PLACER LOCATION.

In figuring the missing course and distance of line 13–1, reference should be made to the latitudes and departures of courses

1 to 13, included in computing the area by Double Meridian Distances.

The sum of the north latitudes is found to be 2235.61, and the sum of the south latitudes is found to be 1401.16, which latter subtracted from the north latitudes leaves a north latitude of 834.45. In like manner subtracting the sum of the east departures, 2466.42, from the sum of the west departures, 2701.97, leaves a west departure of 235.55.

$$\begin{array}{lrl}
\log & 834.45 = & 2.9214003 \\
\log & 235.55 = & 2.3720831 \\
\hline
\log \cot & 15^\circ\ 46' = & 0.5493172
\end{array}
\qquad
\begin{array}{lrl}
\log & 834.45 = & 2.9214003 \\
\log \cos & 15^\circ\ 46' = & 9.9833449 \\
\hline
\log & 867.07 = & 2.9380554
\end{array}$$

Missing course = S. 15° 46′ E. 867.07 feet.

In the triangle ABC draw AC parallel to DE, whose course is given as S. 33° 34′ E. Line AB we have found to be S. 15° 46′ E. 867.07 feet.

$$\begin{array}{rr}
A = & 33^\circ\ 34' \\
 & 15^\circ\ 46' \\
\hline
 & 17^\circ\ 48'
\end{array}
\quad
\begin{array}{rr}
B = & 87^\circ\ 19' \\
 & 15^\circ\ 46' \\
\hline
 & 103^\circ\ 05'
\end{array}
\quad
\begin{array}{rr}
C = & 33^\circ\ 34' \\
 & 87^\circ\ 19' \\
\hline
 & 120^\circ\ 53'
\end{array}
\quad
\begin{array}{r}
180^\circ\ 00' \\
120^\circ\ 53' \\
\hline
59^\circ\ 07'
\end{array}
\quad
\begin{array}{rr}
A = & 17^\circ\ 48' \\
B = & 103^\circ\ 05' \\
C = & 59^\circ\ 07' \\
\hline
 & 180^\circ\ 00'
\end{array}$$

$$\sin 59^\circ\ 07' : 867.07 = \sin 103^\circ\ 05' : \ ?$$
$$\sin 59^\circ\ 07' : 867.07 = \sin\ 17^\circ\ 48' : \ ?$$

$$\begin{array}{lrl}
\log & 867.07 = & 2.938054 \\
\log \sin & 103^\circ\ 05' = & 9.988578 \\
\operatorname{colog} \sin & 59^\circ\ 07' = & 0.066404 \\
\hline
\log & 984.09 = & 2.993036
\end{array}
\qquad
\begin{array}{lrl}
\log & 867.07 = & 2.938054 \\
\log \sin & 17^\circ\ 48' = & 9.485289 \\
\operatorname{colog} \sin & 59^\circ\ 07' = & 0.066404 \\
\hline
\log & 307.85 = & 2.489747
\end{array}$$

$$\text{Area} = \tfrac{1}{2}\,(867.07 \times 308.85 \times \sin 103^\circ\ 05')$$

$$\begin{array}{lrl}
\log & 867.07 = & 2.938054 \\
\log & 307.85 = & 2.489747 \\
\log \sin & 103^\circ\ 05' = & 9.988578 \\
\operatorname{colog} & 871.20 = & 5.059882 \\
\hline
\log & 2.994 = & 0.476261
\end{array}$$

Construct the triangle ACF. Line AF is a prolongation of line 12–13, and line CF is a prolongation of line 1–2.

Station	Course	Distance	Latitudes		Departures		D. M. D.	N. Areas	S. Areas
			North	South	East	West			
1– 2	S. 87° 19′ W.	1108.73	....	51.91	....	1107.51	1107.51	....	57490.83
2– 3	N. 67° 50′ W.	303.50	114.51	....	....	281.07	2496.09	285827.20	....
3– 4	N. 77° 35′ W.	297.00	63.86	....	....	290.05	3067.21	195872.00	....
4– 5	S. 28° 36′ W.	796.10	....	698.96	....	381.09	3738.35	....	2612956.90
5– 6	N. 19° 56′ W.	905.00	850.78	....	....	308.54	4427.98	3767236.90	....
6– 7	N. 77° 35′ W.	145.00	31.18	....	....	141.61	4878.13	152100.10	....
7– 8	N. 18° 41′ E.	512.00	485.02	....	164.01	....	4855.73	2355125.54	....
8– 9	S. 71° 08′ E.	962.00	....	311.08	910.32	....	3781.40	....	1176317.89
9–10	S. 53° 05′ E.	537.60	....	322.91	429.82	....	2441.26	....	788307.45
10–11	S. 88° 42′ E.	718.50	....	16.30	718.32	....	1293.12	....	21077.71
11–12	N. 17° 40′ W.	633.00	603.15	....	....	192.10	766.90	462555.61	....
12–13	N. 70° 21′ E.	259.04	87.11	....	243.95	....	715.05	62288.00	....
13– 1	S. 15° 46′ E.	867.07	....	834.45	235.55	....	235.55	....	196554.71
			2235.61	2235.61	2701.97	2701.97		7281005.35	4852705.49
								4852705.49	
								2)2428299.86	
								1214149.93 sq. ft.	

log 1214149.93 = 6.0842721
log 43560 = 4.6390879

log 27.873 = 1.4451842

				$A = 103^\circ\ 55'$
$A = 70^\circ\ 21'$	$C = 33^\circ\ 34'$	$180^\circ\ 00'$	$F = 87^\circ\ 19'$	$C = 59^\circ\ 07'$
$33^\circ\ 34'$	$87^\circ\ 19'$	$120^\circ\ 53'$	$70^\circ\ 21'$	$F = 16^\circ\ 58'$
$103^\circ\ 55'$	$120^\circ\ 53'$	$59^\circ\ 07'$	$16^\circ\ 58'$	$180^\circ\ 00'$

$$\sin 16^\circ\ 58' : 984.09 = \sin 103^\circ\ 55' : ?$$
$$\sin 16^\circ\ 58' : 984.09 = \sin 59^\circ\ 07' : ?$$

log	984.09 = 2.993035		log	984.09 = 2.993035	
log sin	103° 55′ = 9.987061		log sin	59° 07′ = 9.933596	
colog sin	16° 58′ = 0.534892		colog sin	16° 58′ = 0.534892	
log	3273.32 = 3.514988		log	2894.17 = 3.461523	

$$\text{Area} = \tfrac{1}{2}\,(984.09 \times 2894.17 \times \sin 103^\circ\ 55').$$

log	984.09	= 2.993035
log	2894.17	= 3.461524
log sin	103° 55′	= 9.987061
colog	87120	= 5.059882
log	31.732	= 1.501502

The area of the placer was found to be 27.873 acres. The area of the quadrilateral *ADBE* is therefore the difference between 35 acres, the required acreage, and 27.873 acres, which is 7.127 acres. The area of the triangle *ABC* was found to be 2.994 acres; then the area of the quadrilateral *ADCE* is the difference between 7.127 acres and 2.994 acres, or 4.133 acres.

The area of the triangle *ACF* has been found to be 31.732 acres. Therefore the area of the triangle *DEF* is 31.732 acres plus 4.133 acres, or 35.865 acres.

By geometry

$$31.732 : 984.09^2 = 35.865 : DE^2$$
$$31.732 : 3273.32^2 = 35.865 : EF^2$$
$$31.732 : 2894.17^2 = 35.865 : DF^2$$

log 984.09^2 = 5.986070	log 3273.32^2 = 7.029978
log 35.865 = 1.554671	log 35.865 = 1.554671
7.540741	8.584649
log 31.732 = 1.501502	log 31.732 = 1.501502
2)6.039239	2)7.083147
log 1046.21 = 3.019619	log 3479.95 = 3.541573
log 2894.17^2 = 6.923046	DF = 3076.86
log 35.865 = 1.554671	AF = 2894.17
8.477717	AD = 182.69
log 31.732 = 1.501502	EF = 3479.95
2)6.976215	CF = 3273.32
log 3076.86 = 3.488107	EC = 206.63

BC = 307.85	1–2 = 1108.73	12–13 = 295.04
EC = 206.63	BE = 514.48	AD = 182.69
BE = 514.48	E–2 = 1623.21	12–D = 441.73

Another method of working this problem is as follows: The area of the quadrilateral $ADCE$ has been found as in the previous figuring. The following formula will give the altitude:

Let x = altitude.
Let K = cot E − cot A.
Let A = area of $ADCE$ (4.135 acres = 180,033 sq. ft.).
Let D = 984.09 ft., (line AC).

$$x = \frac{1}{K}\left(\pm \sqrt{2\,AK + D^2} - D\right)$$

nat cot 59° 07′ = 0.59809	log 984.09 = 2.9930348
nat cot 76° 05′ = 0.24778	log to square = 2.9930348
K = 0.35031	log 968433.12 = 5.9860696

$$x = \frac{1}{.35031}\left(\sqrt{2 \times 180033 \times .35031 + 968433.12} - 984.09\right)$$

log 200 = 0.3010300	126135.00
log 180033.00 = 5.2553533	D^2 = 968433.12
log 0.35031 = −1.5444525	1094668.12
log 126.135 = 5.1008358	

The square root of 1,094,678.12 is found as follows:

log 1094668.12 = 6.0392436		1046.21
2)6.0392436		984.09
3.0196218 = log 1046.21		62.12

$$\begin{aligned}
\log\ 62.12 &= 1.793231\\
\log\ .35031 &= -1.544452\\
\log\ 177.33 &= 2.248779 = x
\end{aligned}$$

In the right triangle ADo, we have $Do = 177.33$ feet, the angle $D = 70° 21' - 56° 26' = 13° 55'$.

log 177.33 = 2.248779	log 177.32 = 2.248779
log tan 13° 55′ = 9.394073	log cos 13° 55′ = 9.987061
log 43.94 = 1.642852	log 182.69 = 2.261718

It is seen here that line AD, 182.69, checks with the former work.

In the right triangle CEn, we have $Cn = 177.33$ feet, and the angle $E = 59° 07'$.

log 177.33 = 2.248779	log 177.33 = 2.248779
log cot 59° 07′ = 9.776769	log sin 59° 07′ = 9.933596
log 106.06 = 2.025548	log 206.62 = 2.315183

Line CE, 206.62, also checks line CE in the first method.

$$\begin{aligned}
984.09 &= AC\\
43.94 &= Ao\\
\hline
940.15 &= oC = Dn\\
106.06 &= nE\\
\hline
1046.21 &= DE
\end{aligned}$$

Calculation of Lode Line

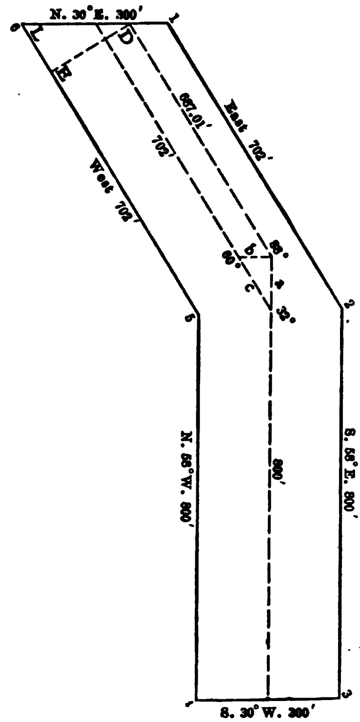


FIG. 91.—MAP OF LODE CLAIM.

Given the boundaries of a claim, calculate a lode line parallel to the side lines, and the points at which the lode line intersects the end lines. No point on the lode line to be in excess of 150 feet from either side line. Lode line to be 1500 feet long.

The boundaries are as follows: Beginning at Cor. No. 1, thence E. 702 ft. to Cor. No. 2; thence S. 58° E. 800 ft. to Cor. No. 3; thence S. 30° W. 300 ft. to Cor. No. 4; thence N. 58° W. 800 ft. to Cor. No. 5; thence W. 702 ft. to Cor. No. 6; thence N. 30° E. 300 ft. to Cor. No. 1, the place of beginning. (See Fig. 91, which shows conditions necessarily greatly exaggerated.) The side b is drawn parallel to the end lines in the triangle whose sides are a, b, and c.

$$800 + a + 702 - c = 1500$$
$$1502 + a - c = 1500$$
$$c - a = 2$$

$$c = \frac{a \sin 88^\circ}{\sin 60^\circ}$$
$$\frac{a \sin 88^\circ}{\sin 60^\circ} - a = 2$$
$$a \sin 88^\circ - a \sin 60^\circ = 2 \sin 60^\circ$$
$$a = \frac{2 \sin 60^\circ}{\sin 88^\circ - \sin 60^\circ}$$

$$\begin{array}{rl} \sin 60^\circ = & 0.86603 \\ & 2 \\ \hline & 1.73206 \end{array}$$

$$\begin{array}{rl} \sin 88^\circ = & 0.99939 \\ \sin 60^\circ = & 0.86603 \\ \hline & 0.13336 \end{array}$$

$$\begin{array}{lrl} \log 1.73206 = & & 0.238698 \\ \log 0.13336 = & & -1.125025 \\ \hline \log \quad 12.99 = & & \bar{1}.113673 \end{array}$$

In the triangle whose side a we have found to be 12.99, the sides b and c are found as follows:

$$\sin 60°: 12.99 = \sin 32°: ?$$
$$\sin 60°: 12.99 = \sin 88°: ?$$

log	12.99 = 1.113673		log	12.99 = 1.113673
log sin	32° = 9.724210		log sin	88° = 9.999735
colog sin	60° = 0.062469		colog sin	60° = 0.062469
log	7.95 = 0.900352		log	14.99 = 1.175877

$$800 + 12.99 + 702 - 14.99 = 1500 = \text{lode line.}$$

800.00	702.00	687.01
12.99	14.99	812.99
812.99	687.01	1500.00

The distance of the lode line at its intersection with line 6–1 is found to be 157.95 feet from Cor. No. 6, and 142.05 feet from

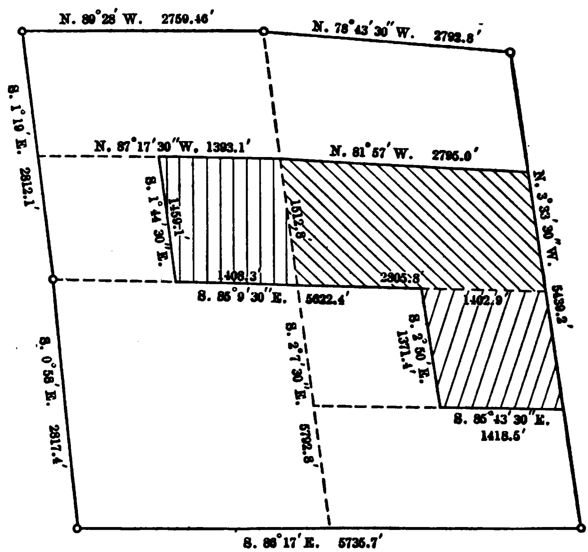


FIG. 92. — MAP OF GOVERNMENT SECTION.

Cor. No. 1, by adding the distance 7.95 feet (b) in one case, and subtracting in the other, to and from 150 feet.

In the triangle DEL draw DE perpendicular to the side line.

Multiplying the side LD (157.95) by the sine of the angle L, 60°, we get the distance of the lode line from line 5–6, which is 136.80 feet.

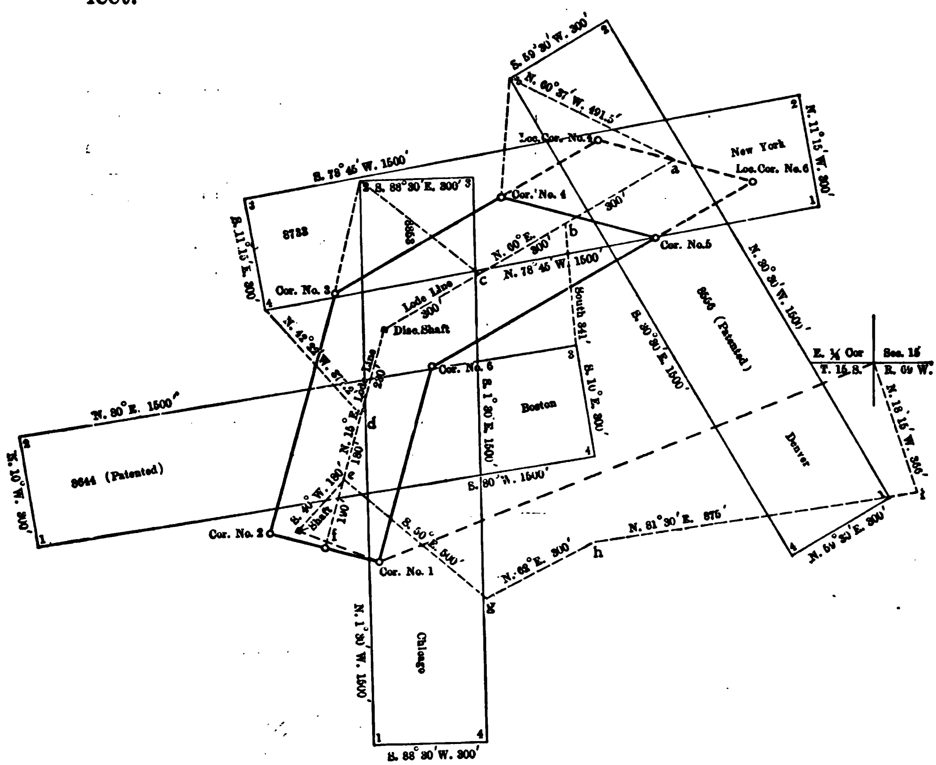


FIG. 93.—MAP OF LODE CLAIM SHOWING CONFLICTING CLAIMS.

Subdivision of Section.—Give the boundaries of a section (Fig. 92) to determine the boundaries of the S. E. ¼ of the N. W. ¼, the S. ½ of the N. E. ¼ and the N. E. ¼ of the S. E. ¼ sections.

S. 86° 17′	E.	5735.7	feet.
N. 3° 33′ 30″	W.	5439.2	feet.
N. 78° 43′ 30″	W.	2792.8	feet.
N. 89° 28′ 30″	W.	2759.46	feet.
S. 1° 19′	E.	2812.1	feet.
S. 0° 58′	E.	2817.4	feet.

General Figuring.—In Fig. 93 we have an example of a problem given the writer in his examination for a commission as

United States Deputy Mineral Surveyor. Given the data shown in the figure, calculate boundaries of St. Louis Lode (cutting off at intersection of end line with Sur. No. 8556 Denver Lode), section tie directly, ties to conflicting claims, and conflicts in each case, also ties to improvements. Then write up the notes, giving imaginary bearings from corners and imaginary dimensions to improvements. Do not exclude Surs. Nos. 8733 and 8853, New York and Chicago lodes, and state why.

South Dakota.[1]— Following is a partial list of questions asked in South Dakota:

'1. I run 360 feet on a descent of 1 foot in 15 feet, thence 240 feet on an ascent of 11° from the horizontal, thence 400 feet on a descent of 1 foot in 16 feet, thence 250 feet up an ascent of 35°.

'Required total horizontal distance, also difference of level of the initial and terminal points. State a full solution with sketch.

'2. From initial point I run S. 12° E. 650 feet, and am intercepted by a pond. From 650-foot point I run S. 82° E., a distance sufficient to clear pond, thence S. 28° W. 420 feet to flag on line in advance of pond, then S. 12° E. 460 feet to terminal point.

'Required the length of line from initial to terminal point. State a full solution with sketch.

'3. I run S. 38° E. and at 380 feet turn off a base N. 82° E. 520 feet, from the eastern extremity of which a flag on line in advance of river bears S. 8° E.

'What is the distance of flag from initial point? State a full solution of sketch.

'4. Course No. 2 of Delta mining claim is broken into by a rock bluff, unfavorable to accurate chainage. To obtain the bearing and length of this line, I run from one extremity on a random line S. 28° E. 610 feet, thence N. 82° E. 260 feet, thence S. 12° W. to a point which from the data so far obtained I find to be on my random line; thence I continue the first random 340 feet further and arrive at a point from which the other extremity of said course No. 2 bears S. 62° W., 110 feet distant.

'What is the bearing and length of course No. 2? What angle do I deflect from the course S. 12° W. in order to line in with the first random? State a full solution with sketch.

'5. The two extremities of a straight line forming a portion of

[1] These questions were kindly furnished by Prof. Mark Ehle, Rapid City, South Dakota.

the boundary of a mining claim are not conveniently accessible, but a convenient base can be had, from each extremity of which both extremities of said boundary can be seen.

'1st. Illustrate this condition with sketch.

'2d. State the measurements, both linear and angular, which are absolutely essential to a solution.

'3d. State briefly the trigonometric solution and their respective purposes, with their respective formulæ.

'4th. Trace the process to a final resulting course and distance.

A numerical example is not asked.

'6. State a convenient formula applicable to what is known as a "broken base," using the number of minutes in the deflection angle of the second component.

'7. Given the following consecutive courses of a mining claim:

From Cor. No. 1 to Cor. No. 2, = S. 28° 40′ W. 503 feet;
From Cor. No. 2 to Cor. No. 3, = N. 70° 30′ W. 476 feet;
From Cor. No. 3 to Cor. No. 4, = N. 9° 35′ E. 485 feet;
From Cor. No. 4 to Cor. No. 5, = ? 343 feet;
From Cor. No. 5 to Cor. No. 1, = N. 79° 50′ E. ? feet;

'1st. Required bearing of line 4–5 and length of line 5–1.

'2d. If by actual survey of all the sides, it is found that the line 5—1 is N. 79° 55′ E. 395 feet, state a traverse showing the closing errors; then

'3d. Balance the survey on the assumption that the measurements have equal weights.

'4th. Deduce the resulting courses and distances of the closing survey for record.

'5th. Compute the area of the figure so enclosed by the method of D. M. D. State full solution with sketch.

'8. An incline descends on a dip of 30°. It is determined to sink a shaft to intercept incline, the shaft to be at a point 450 feet from mouth of incline; the surface from mouth to shaft descending at a rate of 1 foot in 75.

'How deep will the shaft be?

'9. What is azimuth?

'10. Observe Polaris at greatest elongation at a place in latitude 45° 30′ N. Apparent of the star is 88° 44′ 10″.

'What is the star's azimuth?

'State the formula and whole process.

'What are the two hour angles corresponding to eastern and western elongations respectively, counting from culmination, round with the sun to 24 hours, and their equivalents in mean solar time?

'11. If in the last example the star is observed at eastern elongation and its magnetic bearing at that instant is N. 13° 20′ W.:

'What is the magnetic declination?

'Is it to be called East or West?

'State process and reason therefor.

'12. U. S. Revised Statutes (2320) limit lode claims located after May 10, 1872, to 300 feet on each side of the middle of the vein at the surface; suppose you were called upon to make an official survey of such a location under order from this office, and found it to be 350 feet on each side of the middle of the vein at the surface, and you found nothing in the location certificate to dictate to the contrary, what would be your action in respect to such a location? Why? Suppose such a location was 200 feet on one side of the vein and 400 feet on the other, what would your action be? Why?

'13. A lode claim located since May 10, 1872, shows a length of 1529 feet along the centre of the vein at the surface. What would be your action in this case? Why?

'14. The boundaries of a lode location have the following consecutive courses, namely:

'S. 42° W. 800 feet;
'S. 22° W. 600 feet;
'N. 80° W. 90 feet;
'S. 62° W. 200 feet;
'N. 22° E. 600 feet;
'N. 42° E. 800 feet;
'N. 62° E. 190 feet; thence to place of beginning.

'What would your action be on this location if required to make an official survey? Why?

'15. I run N. 89° 56′ W. on a random line between Secs. 30 and 31, and at 73.20 chains intersect the west boundary of town-

ship at a point 22 links north of the corner of Secs. 25, 30, 31, and 36.

'1st. What is the course of the return or true line?

'2d. The position of the ¼ section corner?

'3d. State a short rule for obtaining the return course in these cases, applicable when the fallings are within limits, and apply to the above case.

'16. An order to officially survey a mineral claim is issued to you from this office under date March 12, 1900; said order is based upon a location certificate dated January 10, 1899. Upon proceeding with survey, you find the location as marked on the ground does not conform to the location as recorded, and upon informing your client to that effect, he provides you with a certified amended certificate of location dated March 30, 1900.

'What action would you take in the matter of survey?

'17. Describe fully your instrument, stating its make, age and condition; also its capabilities as to power, illumination and graduation, and its attachments of convenience for safe and accurate work.

'What measure of length have you?

'18. If your telescope has a level, state briefly in writing, how you would adjust it and the horizontal hair.

'19. The usual method for adjusting the vertical hair in a transit for collimation, may or may not place that hair truly in the centre of the telescope. In a well-constructed instrument the displacement will be small; in such case what sensible effect has this displacement upon observations, seeing that the motion of the slide will not project this hair truly along the axis of the telescope?

'20. It is required that you determine the true meridian by direct solar observation. You will make the observation in the presence of the examiner, who will then furnish you with a copy of the nautical almanac. From the data then at hand you will make all necessary calculations, handing in the same complete.

'21. In Latitude 30° N. the sun's declination 20° S. with hour angle 5 hours; the refraction in declination is 8′ 50″.

'Assuming no index error, which would be the correct reading to set off on the declination are, proper for the above date?

'22. In latitude 44° N. the hour angle of the sun 6 hours, I

start a line due north by solar; but find after running a mile in the course so started that I have set off 6′ too much latitude.

'What is the nature and amount of error in course thus induced?

'If in the above the hour angle is 3 hours, what is the nature and amount of error?

'If the latitude is correctly set off, but instead of a declination of 10° S. I set off 10° 10′ S., the hour angle of the sun being 3 hours, what then is the nature and amount of the error thus introduced?

'State, if you can, the differential formulæ applicable to these cases.'

California.[1]— The customary manner of appointment in this and the adjoining states is as follows:

'The surveyor who wishes an appointment, makes application to the Surveyor-General, detailing his qualifications. This application, together with the recommendation from some Deputy Mineral Surveyor of good standing within that district, is then forwarded to the Surveyor-General's office, and in due time the appointment is made. The customary filing of the bonds completes the appointment of the U. S. Deputy.

'If the deputy desire an appointment in any other state or territory, I have found that a recommendation from the Surveyor-General of the state in which the original appointment was made was all that was necessary to obtain a commission in any additional state or territory. Of course new and separate bonds must be filed for each state or territory in which commission is held.'

Oregon.[2]— The examination in Oregon is about as follows:

'1. Fifteen or twenty questions covering the Land Office rulings, the proper markings for corners of government land surveys, the methods of taking latitude by the sun and Polaris, the maximum number of acres allowed in quartz claim, placer, and mill site, kind of corners which may be set in making patent surveys, and various details of procedure in executing such surveys.

'2. Given the notes of a quartz claim (metes, bounds, and ties) and the location of the same, make out notes and preliminary plat of same as if surveyed for patent. This requires the same

[1] Kindness of Henry J. Jory, Los Angeles, California.

[2] From H. G. Moulton, U. S. Deputy Mineral Surveyor, Grant's Pass, Oregon.

work to be done that a Deputy would have to do in making out his office work of such a survey.

'3. Given the plat of the locations of four claims forming one group, and overlapping each other, with a section corner located on one of the centre ones (this plat is furnished by the Surveyor-General), make out notes of a survey for U. S. patent of the group, with plat, calculations, etc. The claims are given on the plat furnished as longer than 1500 feet and wider than 600 feet, so there is a test of ability in getting them within the required limits and at the same time not leave any fractions.

'4. An instrumental examination. Applicant is required to take a transit and determine latitude and meridian by sun and Polaris, checking upon an established meridian, and also to report the courses from a given point to a number of points whose bearing is known.

'Parts 2 and 3 are severe tests of applicant's ability, and the examination as a whole is an exceedingly thorough one. It is the aim of the office to get the best available men of the state as deputies, and the examination is in every way a fair one and free from "catch" questions.'

While this is all the information that the writer has been able to obtain on the subject of examinations for commission as U. S. Deputy Mineral Surveyor, it is safe to say that in no state is the examination more difficult than in Colorado or Oregon. If the applicant is able to pass the examination in either of these two states, the chances are that he will be able to pass in any state where an examination is held.

PROBLEMS [1]

The following are suggested in order to teach the student graphical and trigonometric methods for solving mine-surveying problems:

Problems involving descriptive geometry to determine the intersections of veins, the location of openings to cut intersections of veins and to locate openings when veins are faulted.

In all cases certain assumptions must be made:

(*a*) Except in Problems 4 and 8, the surface is assumed to be a horizontal plane.

[1] From L. E. Young's 'A Study of Mine Surveying Methods,' in *Iowa Engineer*, May, 1904.

(*b*) Veins are assumed to be planes of uniform dip. Intersections of veins are assumed to be straight lines. Except in (*b*) of Problem 3, thickness of veins is not considered.

(*c*) Shafts on veins will be straight but inclined.

(*d*) Except where the grade is specified, tunnels are assumed horizontal, also drifts.

(*e*) Dimensions of shafts and tunnels should not be considered; that is, openings are considered to be straight lines.

(*f*) All inclined shafts to be the shortest possible except in Problem 8.

Problem 1 (Fig. 94)

(*a*) Locate vertical shaft on line '*a–b*' to cut intersection of veins. Find depths of shaft and distance on '*a–b*' from '*A*'.

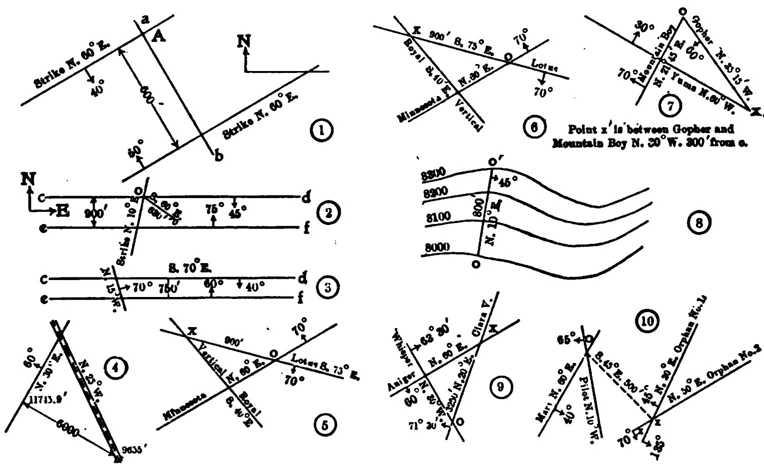


FIG. 94. — PROBLEMS.

(*b*) At 300′ from '*A*' on '*a–b*' is a vertical shaft 200′ deep. Find pitch of inclined shaft and distance on incline from bottom of shaft to intersection of veins.

Draw to scale 1″ = 300′. Take ground line E. and W.

Problem 2

(*a*) Locate vertical shaft to cut intersection of veins. Find depth of shaft and the distance and bearing point to sink, from '*o*'.

(*b*) At '*o*' vertical shaft is sunk to cut vein *EF*. From this

point inclined shaft is sunk on *EF* to cut intersection of the three veins. Find depth of vertical shaft, also bearing and length of incline, also the pitch of inclined shaft.

Draw to scale 1″ = 300′. Take strike of '*a–b*' as ground line.

Problem 3

(*a*) Locate by distance from '*o*' point on '*a–b*' to sink shaft. This shaft inclined and the shortest possible to cut intersection of veins. Find length, pitch, and bearing of shaft.

(*b*) Call intersection '*r*'. Part bounded by '*xor*' is ore. Taking '*xor*' as mean section and 6′ as average thickness, compute No. tons of ore. Heaviness = 170 pounds per cu. ft. Find length of '*or*' '*xr*'.

Draw to scale 1″ = 300′. Take strike of '*cd*' as *G*.

Problem 4

(*a*) Horizontal distance from tunnel mouth (elevation 9653′), to outcrop of vein (elevation 11745′.9), is 6000′. Vein strikes N. 30° E. and dips 63° to the NW. Tunnel is driven N. 25° W. horizontal. Find length of tunnel to cut vein. What depth on vein; will tunnel cut vein knowing that 1700′ NE. from outcrop elevation is 12345′.9 and taking hillside as plane of the three points given.

(*b*) Same as (*a*) tunnel on 2.5 per cent. grade.

Draw to scale 1″ = 2000′0.0. Take *G E* and *W*.

Problem 5

(*a*) Locate vertical shaft on Royal to cut intersection of veins. Find depth of shaft and distance and bearing of point to sink from '*O*'.

(*b*) Locate incline on Lotus. Find depth, etc. Same as (*a*).

(*c*) Locate incline on Minnesota. Find depth, etc. Same as (*a*). Scale 1″ = 300′. Take *G E* and *W* through '*O*.'

Problem 6

(*a*) On the Lotus 200′ NW. from '*o*' an inclined shaft is sunk 300′ in length. From the bottom of shaft a drift extends on vein

N. 75° W. At what distance from shaft should a cross-cut be started to cut intersection of Royal and Minnesota. This cross-cut to be at right angles to drift. Find length of cross-cut.

Draw to scale 1″ = 300′. Take *G E* and *W* through '*o*.'

Problem 7

(*a*) Locate vertical shaft to cut intersection of veins. Find bearing and distance from '*o*'.

(*b*) Vertical shaft is sunk at *x′* to depth of shaft in (*a*). At bottom of shaft cross-cut is run to cut the intersection of veins. Find bearing and length of cross-cut.

(*c*) Incline started at *x′* to cut intersection of veins. Find length, pitch, and bearing.

(*d*) Locate inclines on: Gopher, Mt. Boy, and Yuma, to cut intersection of veins. Find lengths, distances, and bearings from '*o*'.

Draw to scale 1″ = 300′. Take *G E* and *W* through '*o*.' Point *x′* is 300′. N. 30° W. from '*o*'.

Problem 8

(*a*) From '*o*' outcrop bears N. 10° E. and dip of vein is 45°. 800′ up the hill the point '*o*' has an elevation 300′ higher than '*o*'. Find strike of vein.

(*b*) From '*o*' shaft is sunk on vein. From '*o*' tunnel is driven on vein. Find point of intersection and lengths of shaft and tunnel. Shaft perpendicular to outcrop.

Draw to scale 1″ = 300′. Take *G E* and *W*.

Problem 9

(*a*) Find point to sink by bearing and distance from '*o*' to cut intersection of veins. Call point '*x*'. Find depth.

(*b*) At '*x*', due west of '*o*' 5100′, S. 67° 45′ W. 7850′ from '*o*' vertical drill-holes are put down cutting a fault plane at 1000′, 600′, 1000′ respectively. It has been determined that portion above fault plane has moved perpendicular to strike in a south-easterly direction along fault plane 500′. Find point to sink as in

(*a*). Faulting took place, then country eroded to present level condition.

Draw to scale 1″ = 3000′. Take *G E* and *W* through '*o*'.

PROBLEM 10

(*a*) On intersection of Pilot and Mary inclined shaft is down 600′. On intersection of Orphan No. 1 and Orphan No. 2 inclined shaft is down 550′. As the air in both places is bad, we wish to start an inclined upraise from one shaft to connect with the other; this connection to be the shortest possible. Locate points in both shafts so work may be carried on at both ends. Find length, pitch, and bearing of the connection. Reverse traces on Orphan 1 and 2. Compare.

Draw to scale 1″ = 300′. Take *G E* and *W* through '*o*'.

PROBLEM 11

A vein dips 60°, an entry is driven N. 40° W. in the vein on a five-per-cent. grade. What is the strike of the vein?

PROBLEM 12

A drift on a three-per-cent. grade is driven N. 40° E. in a vein whose strike is N. 60° E. Required, the dip of the vein.

PROBLEM 13

A vein dips 45° to the west and strikes N. 12° 30′ E. A drift on the vein is driven N. 16° 30′ E. Required, the grade of the drift.

PROBLEM 14

A vein dips 54° to the east and strikes N. 18° 45′ W. What is the bearing of a drift on the vein driven on a 3-per-cent. grade?

PROBLEM 15

The strike of a vein dipping to the SW. 75° is S. 45° 15′ E. From a given point of outcrop, elevation 3629.4′ the mouth of a tunnel bears S. 40° 10′ W. and distant 3000′ on a vertical angle of −21° 08′. The tunnel is driven straight, horizontal, and N.

12° 15′ E. (*a*) Required, the distance from the mouth of the tunnel to the point at which it intersects the vein. (*b*) Assume the tunnel on a 2-per-cent. grade. (*c*) What is the shortest distance from the tunnel portal to the vein?

Problem 16

A vein (*a*) dips 55° to the northwest and strikes N. 35° 10′ E. A second vein (*b*) strikes N. 35° 10′ E. and on the surface (assumed to be level) is distant from the (*a*) vein 800′. How far from the vein (*a*) should a vertical shaft be put down to pierce the intersection of the veins (1) if (*b*) dips 30° to the northwest; (2) if (*a*) dips 75° to the southeast and (*b*) 55° to the northwest. What will be the depth of shaft in all cases?

Problem 17

A vein dips 43° to the northwest, strikes N. 33° 15′, elevation of outcrop 914.6′. At an elevation of 869.2′ and distant from the outcrop 1000′, an inclined shaft dipping 75° and bearing N. 56° 45′ W. is sunk to intersect the vein. (*a*) Required the depth to which the shaft must be sunk. (*b*) Assume the pitch of the shaft the same, but the bearing S. 89° 14′ W.; what will be the depth of shaft?

Problem 18

The surface has a uniform slope of 10° to the north. A vein strikes east and west and dips 40° to the north.

(*a*) How far north of the outcrop must one go to sink a vertical shaft which shall cut the vein at a depth of 700′? (*b*) What will be the bearing of drifts on the vein driven from the bottom of the shaft on a 3-per-cent. up-grade? (*c*) How far can they be driven so as not to approach nearer than 100′ to the surface?

Problem 19

The vein described in Problem 18 is intersected at a depth of 1000′ by a vertical shaft. From the bottom of the shaft a slope on the vein extends due north 600′. An entry is driven on a 4-per-cent. grade to the southwest from the bottom of the slope for a

distance of 4000′. Required the depth of vertical shaft necessary in order to connect the end of the entry with the surface?

Problem 20

The horizontal distance between two vertical shafts is 1000′, the difference in elevation of the collars of shafts is 291.4′. The depth of shaft sunk from the higher point is 647.2′; from the bottom of this shaft a cross-cut (*a*) is driven towards the other shaft on a 1-per-cent. grade, 436′. The second shaft is 350′ deep. Required the length and grade of cross-cut (*b*) from this shaft to meet the breast of (*a*).

Problem 21

Suppose that the lower shaft described in 20 bears S. 19° 40′ W. of the other and that the cross-cut (*a*) is driven S. 40° W. Required the direction, grade, and length of (*b*).

Problem 22

A vein dips 60° to the south and strikes N. 70° E. Consider the outcrop of the vein as 3650′ elevation. 500′ distant from the outcrop and at an elevation of 3601′ a vertical shaft is sunk to intersect the vein. From this shaft the mouth of a cross-cut tunnel bears S. 60° E, 2000′ on a vertical angle of −30°. The tunnel is driven N. 33° W. on a 2-per-cent. grade to intersect the vein. Required the length of slope on the vein necessary to connect the shaft and the tunnel.

Problem 23

Using the top telescope:

(*a*)

$$\begin{aligned} \text{Elevation} &= 876.42' \\ +V.\ A. &= 52^\circ\ 29' \\ M.\ D. &= 76.49' \\ -H.\ I. &= 2.58' \\ +H.\ Pt. &= 3.45' \\ r &= .301' \\ M.\ D &= \text{Distance from axes of main telescope to point of sight.} \end{aligned}$$

Required *V. D.*, *H. D.*, and elevation.

(*b*)

$$\begin{aligned} \text{Elevation} &= 761.59' \\ -V.\ A. &= 69^\circ\ 55' \\ M.\ D. &= 87.23' \\ +H.\ I. &= 4.28' \\ -H.\ Pt. &= 3.91' \\ r &= .301' \end{aligned}$$

Required $V.\ D.$, $H.\ D.$, and elevation.

(*c*) Elevation of back sight station $= 647.91'$

Backsight	$+V.\ A. = 59^\circ\ 20'$
	$M.\ D. = 63.48'$
	$-H.\ I. = 4.21'$
	$-H.\ Pt. = 3.19'$
	$r = .301'$
Foresight	$-V.\ A. = 57^\circ\ 19'$
	$M.\ D. = 56.13'$
	$+H.\ Pt. = 3.21'$

Required elevation of foresight station.

Problem 24

Using the side telescope:

Elevation of backsight station $= 426.81'$

Backsight	$+V.\ A. = 46^\circ\ 21'$
	$+H.\ Pt. = 3.19'$
	Vernier $= 19^\circ\ 24'$
	$+H.\ I. = 2.26'$
	$M.\ D. = 98.23'$
Foresight	+ Vernier (angle right) $= 176^\circ\ 48'$
	$-V.\ A. = 56^\circ\ 48'$
	$+H.\ Pt. = 4.16'$
	$M.\ D. = 76.24'$

Required elevation of new station.

Problem 25

It is impossible to place staging in a shaft and the second level is not visible from the first level. In order to save time underground, three points in the shaft visible from both levels are

established. The following notes are taken (using the top telescope):

Sta.	Pt.	Az.	M. D.	V. A.	H. I.
100	100 *a*	298°	35.04′	− 89° 20′	3.91′
	100 *b*	202° 32′	37.74′	− 87° 41′	
	100 *c*	237° 40′	36.58′	− 88° 10′	
200	100 *a*	297° 18′	54.43′	+ 54° 03′	3.69′
	100 *b*	293° 57′	51.82′	+ 52° 26′	
	100 *c*	299° 39′	53.13′	+ 53° 06′	

$r = .317'$; 1–2 = 3.33′
1–3 = 1.99′; 2–3 = 3.39′

Required the distance and bearing of 200 from 100.

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